PERFORMANCE OF ENERGY MANAGEMENT CONTROL SYSTEMS (EMCS) IN SELECTED TEXAS LoanSTAR BUILDINGS

A Report by

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Abstract

This report describes an investigation of energy use at various LoanSTAR sites. The effects of installing Energy Management Control Systems (EMCS) on electricity consumption was studied at four LoanSTAR sites: Stroman High School, Victoria High school, Sims Elementary School, and Zachry Engineering Center. In the course of this study, LoanSTAR monitoring data was used to analyze the changes in energy consumption based only on EMCS retrofits. The results will show that the installation of EMCS was successful in reducing energy consumption and/or changing the hourly energy consumption pattern.

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Introduction

Background

"Energy retrofits can cut use and costs." "Direct digital control system saves over 40 percent in energy costs." "University sheds HVAC system for state-of-the-art energy management control." "Vision and technology revolutionize Bryant College." "Control system offers remedy for hospital's energy use ailments." These are some of the headlines found in *Buildings* and *Mechanical Engineering* magazines. Many facility managers are moving toward Energy Management Control Systems (EMCS) or Direct Digital Control systems (DDC) in an effort to reduce energy costs. These efforts have claimed to be successful; however, few reports detail exacly how and/or why the savings occurred.

The following briefly describes the results reported in the above mentioned articles. In general, energy conservation retrofits can reduce the energy use of buildings by 10 to 30 percent, with paybacks typically in the 2- to 4- year range.[1] The Valley Building, an 8-year-old office tower in Renton, Washington achieved a 40 percent savings in energy costs within six months of installing a DDCS.[2] The C.W. Post campus of Long Island University, Brookville, New York, does not report specific monetary savings, rather they report significant maintenance staff labor savings and energy savings due to their EMCS keeping their target setpoints more effectively.[3] Bryant College in Smithville, Rhode Island has achieved energy savings of about $34,000 per year since they installed a DDCS.[4] Craven Regional Medical Center in New Bern, North Carolina, saves an estimated $65,000 in electric costs per year since the installation and proper utilization of an EMCS.[5]

The objective of this report is to determine how successful Energy Management Control Systems have been in reducing energy consumption.

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[1] Claridge, D.E., et al 1994. "Energy retrofits can cut use and costs." *Mechanical Engineering*, August, pp. 64-67.
[2] Editor, 1991. *Buildings*, December, p.16.
[3] Editor, 1992. *Buildings*, September, p. 34.
[4] Mumford, S., 1994. *Buildings,* February, pp. 38-41.
[5] Editor, 1993. *Buildings*, May, p 38.

The LoanSTAR Program[6]

In 1988, the Texas Governor's Energy Management Center (GEMC)[7] received approval from the U.S. Department of Energy to establish a $98.6 million statewide retrofit demonstration revolving loan program, the LoanSTAR (Loans to Save Taxes and Resources) program. The LoanSTAR program uses a revolving loan financing mechanism to fund energy-conservation retrofits in state and local government buildings and public schools. Potential retrofit projects are identified by energy audits conducted by engineering teams under contract to the Texas SECO. Each proposed retrofit competes for funds on the basis of the estimated payback period, the ability to repay the loan through energy savings, an engineering assessment of the viability of the retrofit, and the feasibility of monitoring the project effectively.

The projects funded by the LoanSTAR program primarily include retrofits to lighting, HVAC systems, building shell, electric motors, and EMCS.

The LoanSTAR Monitoring and Analysis Program (MAP) was designed to serve the differing needs of the many participants in the LoanSTAR revolving loan program. The energy monitoring program's first objective is to determine whether retrofits save as much as estimated in audits. The second objective of the MAP is to reduce energy costs of a building by using the monitored data to evaluate its energy-using characteristics, and to diagnose opportunities for improved operations. The final major objective of energy monitoring is the establishment of an end-use database for institutional and commercial buildings in Texas.

The LoanSTAR MAP is not set up to collect monitoring data based on individual retrofits. This would be too costly; therefore, tracking the performance of groups of retrofits was chosen over tracking of specific retrofits. This report evaluates the LoanSTAR monitored data in order to isolate the changes in energy usage based only on EMCS retrofits.

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6 Turner, W.D., 1990. "Overview of the Texas LoanSTAR Monitoring Program," *Proceedingts of the Seventh Annual Symposium on Improving Building Systems in Hot and Humid C limates*, College Station, Texas: Texas A&M University. October 9-10, pp. 28-34

7 The GEMC is now called the Texas State Energy Conservation Office (SECO)

Methodology

Site Selection

The LoanSTAR program currently monitors 90 sites. Sites studied in this report were chosen based on the following:

a) EMCS retrofit was completed,
b) whole building and limited sub-metered hourly data were collected (utilizing one-to four-channel data acquisition systems or data loggers), and
c) ease of separating EMCS retrofit data from whole building data.

The final list of sites studied is:

a) Stroman High School (SHS), Victoria Independent School District,
b) Victoria High School (VHS), Victoria Independent School District,
c) Sims Elementary School (SIM), Fort Worth Independent School District, and
d) Zachry Engineering Center (ZEC), Texas A&M University, College Station.

A data summary notebook is prepared by the Monitoring and Analysis Task of the Texas LoanSTAR program. It provides various plots, giving an historical look at all of the data that has been collected for all of the LoanSTAR sites. Zachry Engineering Center (ZEC) data summary plots are included as a comparison to the methodology used in this report. The charts and table prepared for the other sites were not prepared for ZEC.

Data Reduction

The raw data were obtained from a database maintained by the Energy Systems Lab (ESL) at Texas A&M University under the LoanSTAR MAP. A number of data loggers were installed to collect specific consumption data for each site. The location of the data loggers is indicated on monitoring diagrams, which are included for each site in the Appendices.

The data was extracted from the database using an ESL program called "Getdatc." It is a simple program that expedites the retrieval of data from the LoanSTAR database. It allows the user to obtain columns of logger channel data and to perform calculations on the data quickly and easily. Getdatc outputs the data with timestamps and, when necessary, bad data marks (-99).[8] Data was retrieved for a

[8] Getdatc is copyrighted public domain software developed by the Energy Systems Laboratory, Texas A&M University, Mechanical Engineering Department, College Station, TX 77843-3123

period defined as the report period, which varies from site to site. In all cases, the report period commenced on the monitoring start date for the study site . The report periods for each site are as follows:

Stroman High School	6/5/91 through 6/4/94
Victoria High School	6/5/91 through 6/4/94
Sims Elementary School	10/1/91 through 5/31/95
Zachry Engineering Center	5/31/89 through 10/29/94

To facilitate subsequent data manipulation, the report periods were subdivided into annual blocks of data. For this report, the "whole building" data was extracted. A list showing the information contained in the whole building data set is shown in Figure 1. The output was in the form of an ASCII file, which could be edited and imported into other software for further manipulation.

In order to separate the effects of other retrofits, a list of channels and equations associated with the whole building calculations was reviewed. This list is included in each site Appendix. As an example, the listing for Stroman High School is shown in Figure 1.

Figure 1: Getdatc "listwb" output for Stroman High School

Cp	Name	Expression
1	wbele	ch0323
2	wbcool	ch0324/1000
3	wbheat	ch0326*0.00103
4	oadrybulb	ch0827
5	oarh	dp2rh(ch0827,ch0828)
6	chiller	ch0325
7	windspeed	ch0829

channel ID	Description
0323	Whole Bldg (kWh/h) (126,8)
0324	ChW (kBtu) (126,9)
0325	Chiller (kWh/h) (126,10)
0326	Gas Meter (cuft) (126,11)
0827	VCT Dry Bulb (Victoria) (850,8)
0828	VCT Dew Point (Victoria) (850,9)
0829	VCT Wind Speed (Victoria) (850,10)

The monitoring diagram in Appendix A, Tab A-3 shows the location of the channel where the consumption is measured. Electricity consumption is being examined in this report. This includes all channels which are kilowatt-hour per hour (kWh/h) (channels 0323 and 0325 in Figure 1).

Stroman High School had three retrofits: install an EMCS, replace absorption chiller with electric chiller, and rewire hallway wiring. The effects of the new electric chiller consumption can be eliminated by subtracting chiller consumption (channel 0325, measured at the chiller) from whole building electricity consumption (channel 0323, measured before the electrial main panel). Similar reasoning is used for the data reductions of the other study sites.

Once the data were extracted from the LoanSTAR database, the data file was reduced to two columns of data: decimal date and consumption. This was done using a MS DOS routine called "gawk-f." A *.awk file was created using a text editor. It contains a statement which specifies the column numbers corresponding to the columns of data to be extracted from the getdatc *.acs file. The output file is in ascii format. This process was repeated for all consumption categories to be studied.

Next, the output data file was transformed from columnar format to tabular format using an ESL program called "ColRow3D." [9] It is a columnar data manipulation program which processes hourly energy consumption data to produce a "new" file containing a spread sheet compatible data matrix. ColRow3D transforms each day's worth of data into one row in the matrix. For example, a leap year's worth of hourly data (8764 lines) will be compressed down to just 366 lines of data. The ColRow3D output file was opened in Microsoft Excel for further manipulation.

After each ColRow3D file was opened in MS Excel, they were combined into one .xls worksheet, covering the entire report period. At this point, the data was in consecutive date order. Columns were inserted at the beginning of the worksheet to input sort parameters, which are:

1/0	weekday/weekend
A/B	pre-/post-retrofit
S/NS	semester/non-semester

Ones and zeros were input into the '1/0' column, where a "1" indicates a weekday and a "0" indicates a weekend. A's and B's were input into the "A/B" column, where an "A" indicates a pre- retrofit date and a "B" indicates a post- retrofit date. S's and NS's were input in the "S/NS" column, where an "S" indicates a semester day and a "NS" indicates a non-semester day.

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[9] ColRow3D is copyrighted public domain software developed by the Energy Systems Laboratory, Texas A&M University Mechanical Engineering Department, College Station, TX 77843-3123

A school district schedule was obtained for each site which indicates holidays, breaks, and days when school was not in session. For this report, all holidays, semester breaks and summers were considered non-semester days. The summers were categorized as non-semester for the two independent school districts, even though they held summer school sessions. Consumption during the summer, even with summer school in session, was significantly less than normal school year consumption. In order to avoid falsely reducing the daily average data, the summers were categorized as non-semester.

For cells which contained a "-99" (missing data) or a "0", the content of the cell was replaced with a blank cell. This allows mathematical functions to be used on the data without including erroneous data or zeroes, which would result in bad results (either too large or too small of totals or averages).

The hourly data for each date was summed to obtain total daily data. The total daily consumption was plotted against the day of year for each energy consumption category. This is the timeline plot shown in each site Appendix, Figure 3. The total monthly consumption was then calculated. The data were presented in tabular format in each site Appendix, Table 2. These calclulations were performed for each consumption category.

Next, the "other electric" data was sorted on pre-/post-retrofit (A/B) and semester/non-semester (S/NS). The daily totals were summed for post-retrofit, semester (B, S) and post-retrofit, non-semester (B, NS). The sort category totals are represented as a percentage of whole building electricity consumption in a pie chart, shown in each site Appendix, Figure 4. The sort totals were then multiplied by the appropriate cost of energy ($/unit of energy) to obtain the total cost of energy. The data were presented in tabular form in each site Appendix, Table 1

Average hourly consumption (other electric) was calculated by sorting the data based on (1) semester/non-semester (S/NS), (2) weekday/weekend (1/0), and (3) pre-/post-retrofit (A/B). This yielded eight sort categories:

S-1-A	semester/weekday/pre-retrofit
S-1-B	semester/weekday/post-retrofit
S-0-A	semester/weekend/pre-retrofit
S-0-B	semester/weekend/post-retrofit
NS-1-A	non-semester/weekday/pre-retrofit
NS-1-B	non-semester/weekday/post-retrofit
NS-0-A	non-semester/weekend/pre-retrofit
NS-0-B	non-semester/weekend/post-retrofit

The hourly consumption (other electric) was averaged for each sort category. This represents the average hourly consumption for each hour of the day. It was calculated for only those hours when the equipment was actually on. The average hourly consumption was plotted against hour of day to obtain daily profiles, which are shown in each site Appendix, Figure 5.

Summary of Results

All sites showed both reductions and increases in "other" electricity consumption. The term "other" is defined differently for each site. For Stroman and Victoria High Schools, it is whole building electricity minus chiller electricity consumption. For Sims Elementary Schools, it is whole building electricity minus lighting electricity consumption. For Zachry Engineering Center, whole building electric was analyzed instead of "other" electricity consumption.

Table 2 summarizes the difference in other electric consumption for all study sites except Zachry Engineering Center. Stroman and Victoria High Schools both showed reductions in other electricity consumption for each category except semester/weekend. Sims Elementary School showed reductions in other electricity consumption for each category except semester/weekday. Possible explanations for these increases are discussed in each site Appendix.

Table 3 summarizes the whole building electricity consumption for all sites, for the pre-retrofit period and the most recent year of post-retrofit period. The square footage of each site is also shown in this table. Table 4 summarizes the whole building electricity consumption for all sites, normalized on a square footage basis. From the data shown in both of these tables, one can see that Stroman and Victoria High Schools are relatively low energy use sites, while Sims Elementary School and Zachry Engineering Center are relatively high energy use sites

Table 2: *Summary of Differences in "Other Electric" Consumption*

	# days in sort category	Average Daily Consumption kWh/day	Difference in Average Daily Consumption kWh/day	% Difference in Average Daily Consumption
STROMAN HIGH SCHOOL				
Semester				
weekday-pre	91	5,210		
weekday-post	394	4,525	-685	-13.15%
weekend-pre	35	2,206		
weekend-post	149	2,395	189	8.57%
Non-semester				
weekday-pre	79	3,557		
weekday-post	241	3,225	-332	-9.33%
weekend-pre	33	2,060		
weekend-post	92	1,930	-130	-6.31%
VICTORIA HIGH SCHOOL				
Semester				
weekday-pre	91	7,877		
weekday-post	394	6,889	-988	-12.54%
weekend-pre	35	3,674		
weekend-post	149	4,245	571	15.54%
Non-semester				
weekday-pre	79	6,159		
weekday-post	241	5,182	-977	-15.86%
weekend-pre	33	4,180		
weekend-post	92	3,017	-1,163	-27.82%
SIMS ELEMENTARY SCHOOL				
Semester				
weekday-pre	514	1,453		
weekday-post	229	1,617	164	11.29%
weekend-pre	192	861		
weekend-post	88	444	-417	-48.41%
Non-semester				
weekday-pre	148	1-517		
weekday-post	66	1,479	-38	-2.48%
weekend-pre	72	1,235		
weekend-post	543	-692	-692	-56.03%

Table 3: ***Summary of Whole Building Electricity Consumption, pre- and post-retrofit periods***

Site	Pre-Retrofit Period kWh	Post-Retrofit Period kWh	Conditioned Area sq. ft.
Stroman High School	1,207,697[10]	1,184,318[11]	210,414
Victoria High School	1,499,242[12]	1,845,529[13]	257,014
Sims Elementary School	1,816,566[14]	660,673[15]	62,400
Zachry Engineering Center	14,727,147[16]	8,555,071[17]	324,400

Table 4: ***Summary of Whole Building Electricity Consumption per square foot, post-retrofit***

Site	annual consumption per square foot kWh/SF/year[18]	annual cost per square foot $/SF/year
Stroman High School	5.63	.01570
Victoria High School	7.18	.02002
Sims Elementary School	10.59	.07138
Zachry Engineering Center	26.37	.07352

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Figures 2 through 5 show the average hourly profiles for each study site. The changes in other electricity consumption are easier to see in these figures. Detailed discussions of these plots are contained in the site Appendices. The nighttime consumption (5:00 p.m. to 6:00 a.m.) dropped for all sites. The increases in consumption seen in Table 2 can be seen in the average hourly profiles as well. More interesting to note is the change in the profile itself. In most cases, the nighttime consumption dropped, with a steeper increase to daytime levels in the morning and a steeper decrease to nighttime levels in the afternoon.

In looking only at Tables 2-4, and the average hourly profiles, the conclusion can be made that EMCS retrofits at the study sites have been successful. Further study is required to pinpoint the reasons for increased semester/weekend consumption at Stroman and Victoria High Schools, and semester/weekday consumption at Sims Elementary School.

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[10] June 1991 - January 1992 (8 month period)
[11] June 1993 - May 1994 (12 month period)
[12] June 1991 - January 1992 (8 month period)
[13] June 1993 - May 1994 (12 month period)
[14] October 1991- April 14, 1994 (30-1/2 month period)
[15] June 1994 - May 1995 (12 month period)
[16] June 1989 - March 1991 (21 month period)
[17] October 1993 - September 1994 (12 month period)
[18] based on post-retrofit period consumption reported in Table 3

Figure 2a: *SHS Semester Average Hourly Profile*

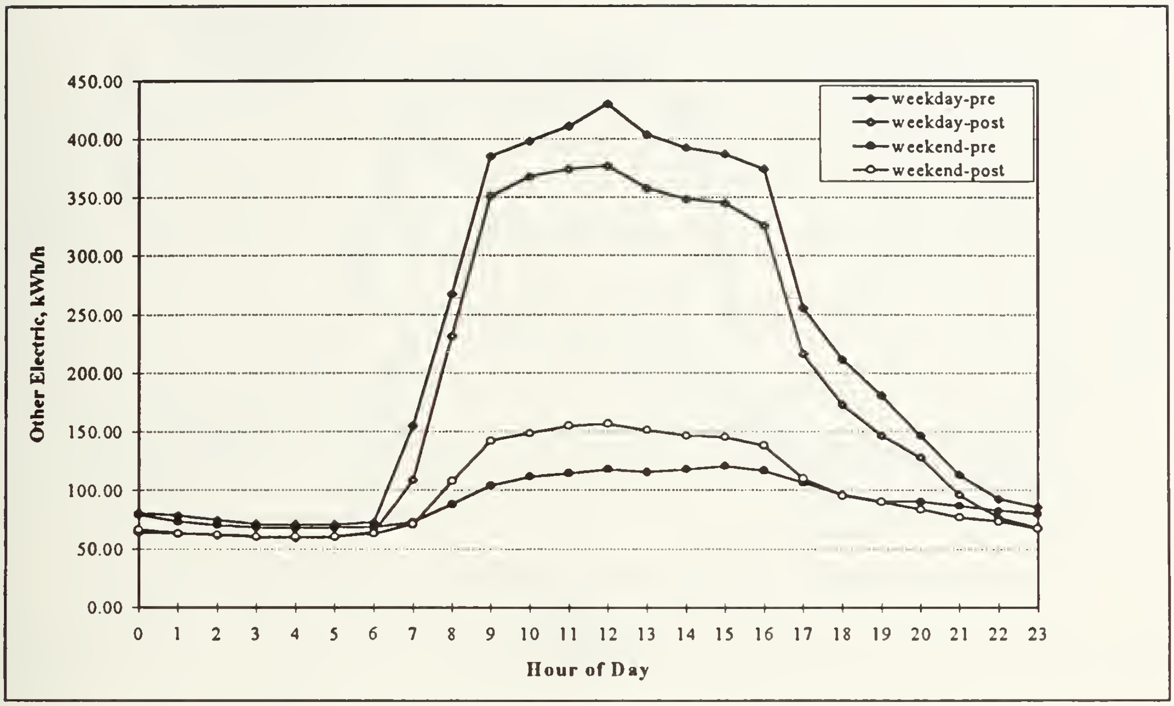


Figure 2b: *SHS Non-semester Average Hourly Profile*

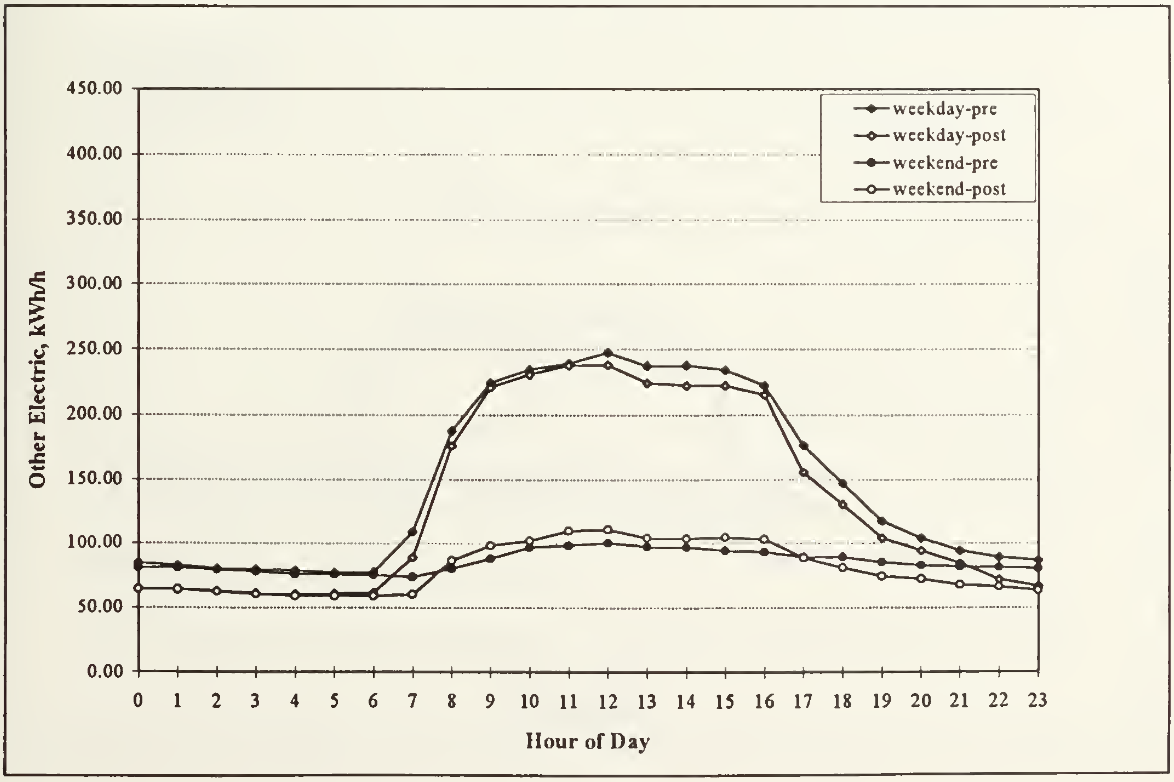


Figure 3a: *VHS Semester Average Hourly Profile*

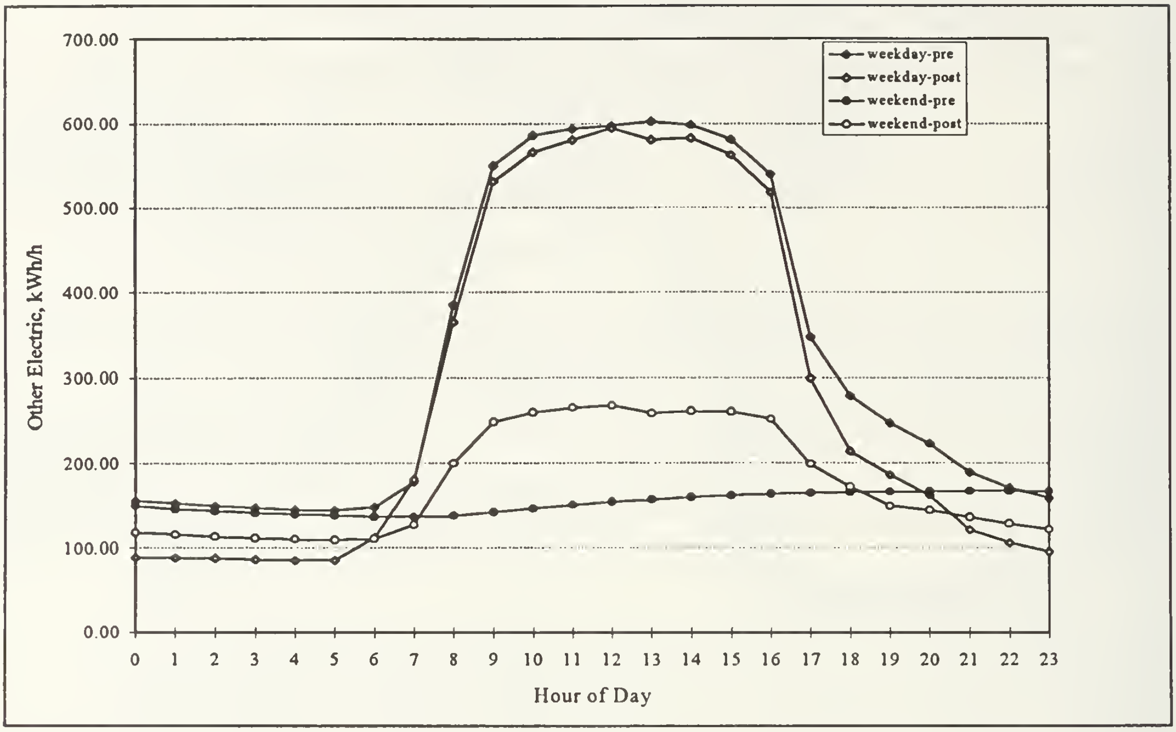


Figure 3b: *VHS Non-semester Average Hourly Profile*

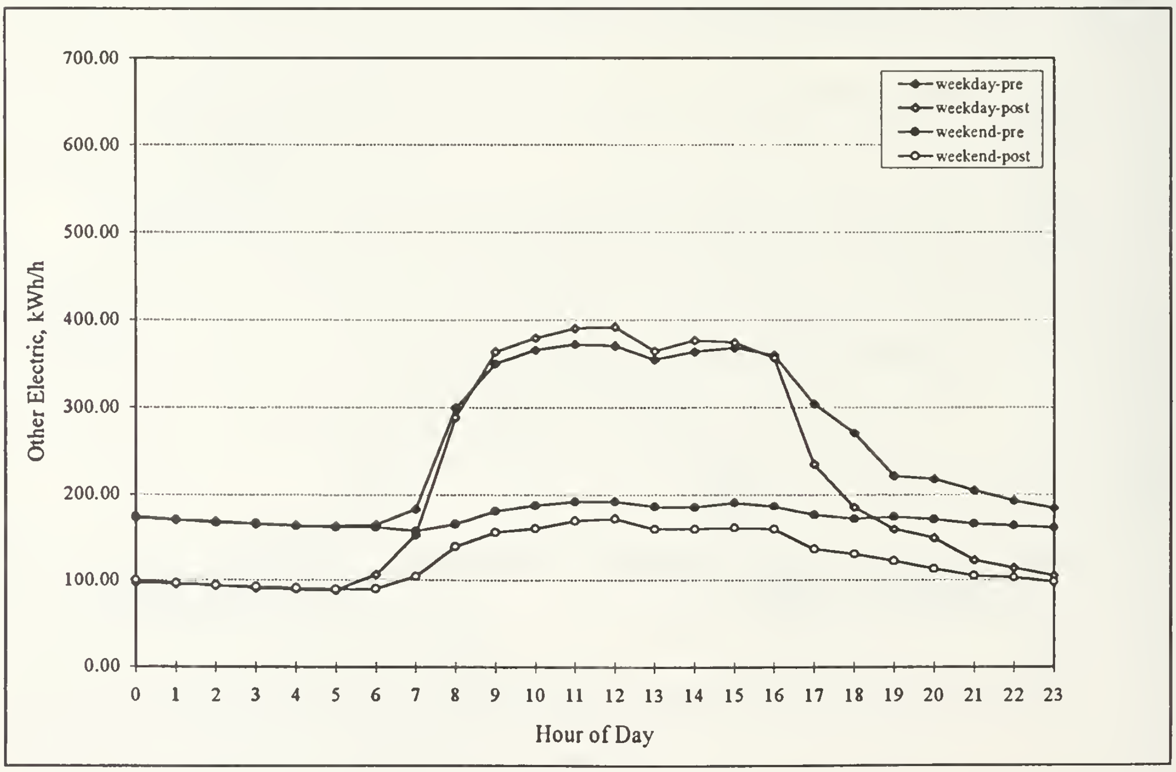


Figure 4a: *SIM Semester Average Hourly Profile*

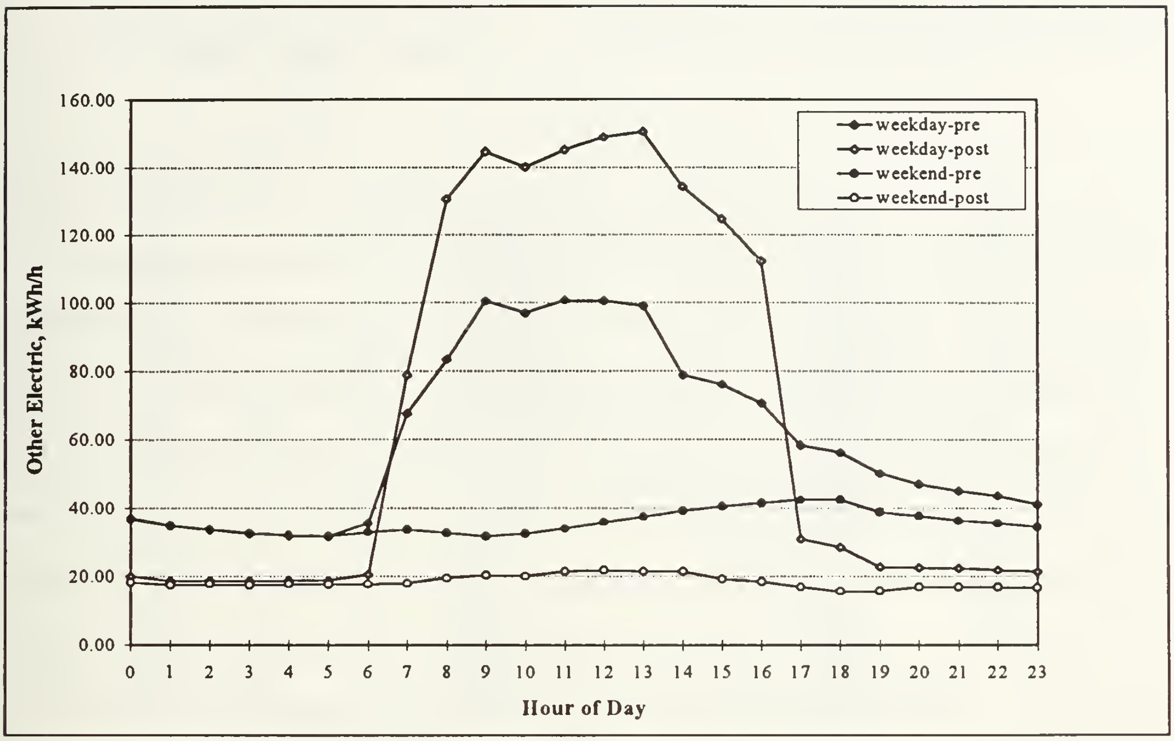


Figure 4b: *SIM Non-semester Average Hourly Profile*

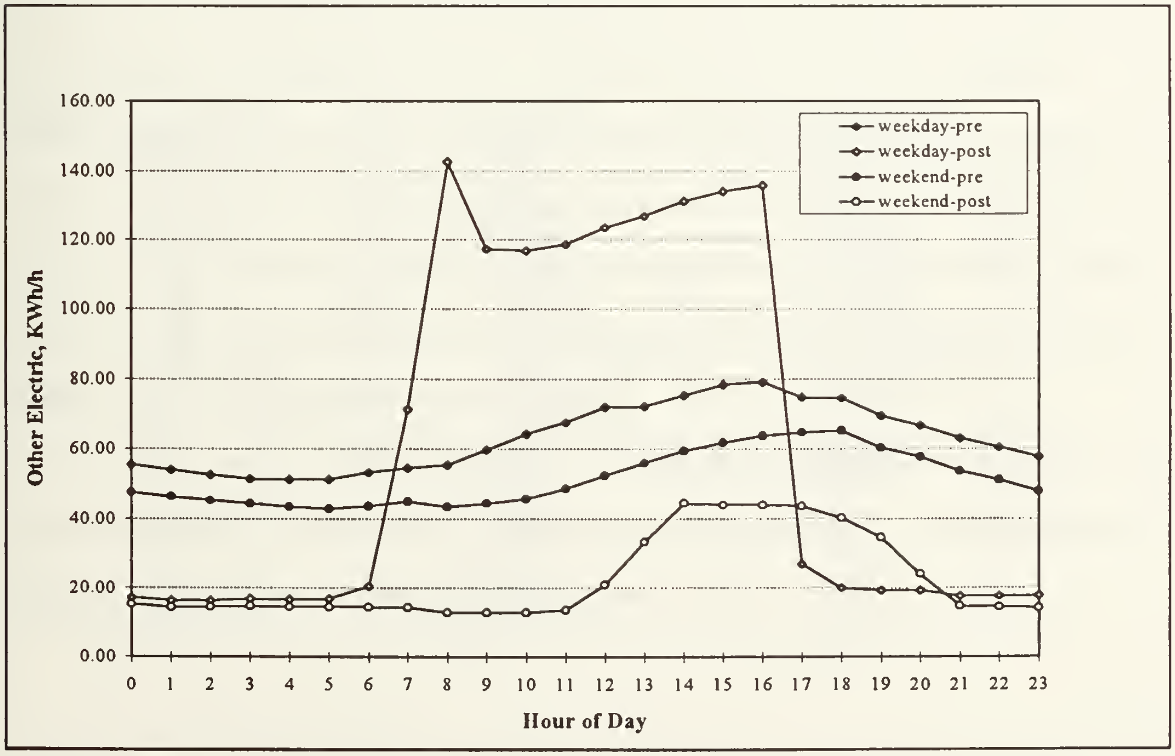
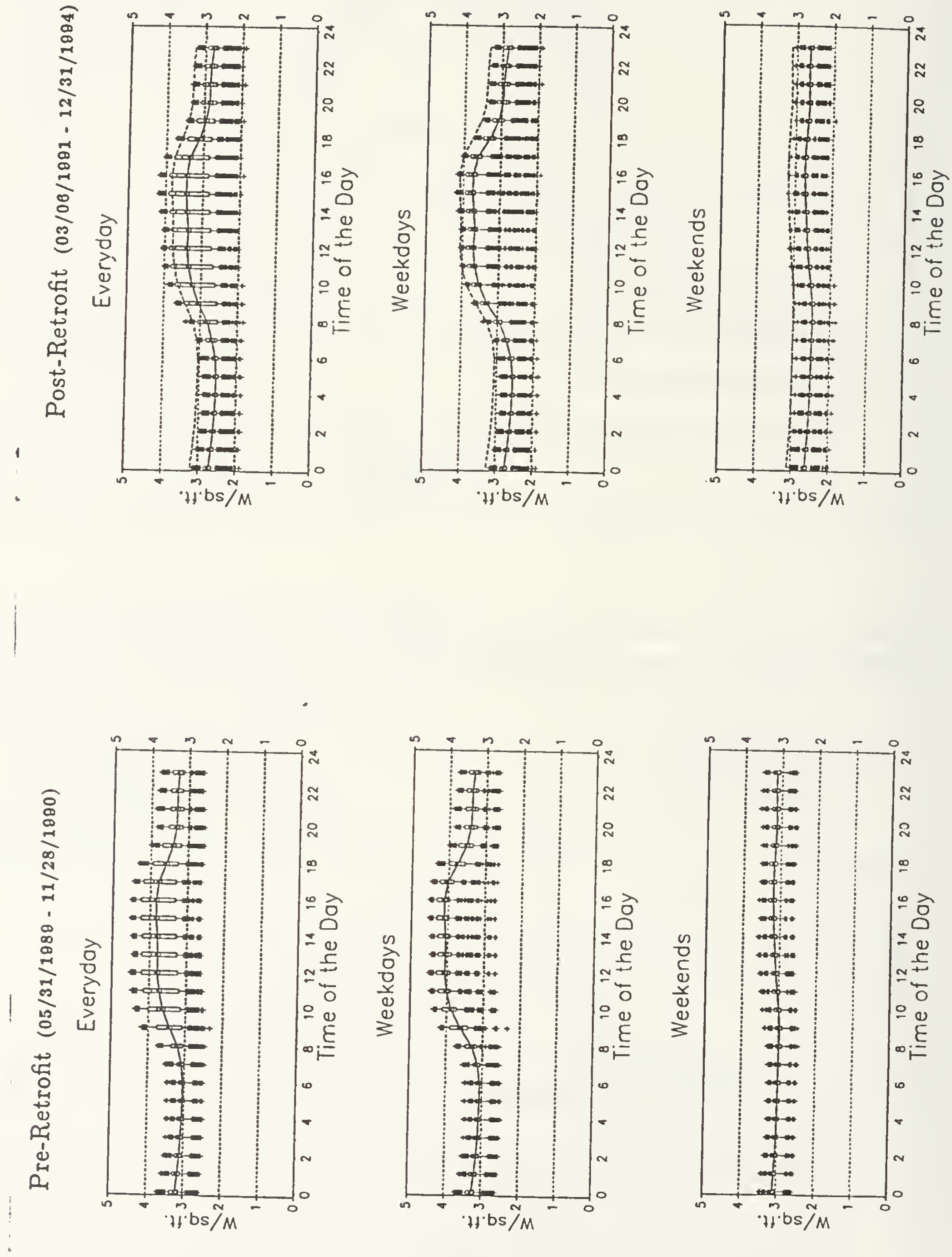


Figure 5: ***ZEC Whole Building Electric as W/sf***



A. STROMAN HIGH SCHOOL

A.1 Site Description[1]

Stroman High School is located in Victoria, Texas. It consists of nine separate buildings with a total floor area of 210,414 square feet. Classrooms are heated and cooled by individual hydronic fan coil units. The first floor is heated and cooled by a hydronic air handler, and there are single air handlers on floors two through four to supply outside air to each floor. The two-story Unit B contains the auditorium, choir room, band room, and drafting classrooms. It is heated and cooled by air handlers. The band hall has direct expansion cooling as well, operating whenever the hydronic air handler does not provide cooling, in order to prevent humidity problems. Unit C is single story, housing the cafeteria and kitchen. It is heated and cooled by hydronic fan-coil units (six in the cafeteria, two in the kitchen). Units D and E are in one contiguous building, a two-story structure containing the library, gymnasium, locker rooms, and the main mechanical room. HVAC is provided by a hydronic air handler in the library, and by heating/ventilation units in the remaining athletic facilities. Unit F is a two-story building containing the science classrooms. It is heated and cooled by hydronic fan-coil units. Unit G is a single story shop building, containing several pieces of electrical equipment, from band saws to drills. It is heated and cooled by direct expansion units with gas furnaces. Chilled water and hot water for units A through G is provided by a 460 ton electric chiller and a 5,050 MBtu gas fired steam boiler. Auxiliary equipment includes a 50 horsepower chilled water pump, a 40 horsepower condenser water pump, a 30 horsepower cooling tower fan, and a 20 horsepower hot water pump.

There are also three athletic buildings just north of the main buildings that house the girls' gym, the field house, and the "athletic dome," in which weight training takes place. All three buildings are heated and cooled by direct expansion units with gas furnace.

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[1] Adapted from: Landman, D.S., 1995. "Preliminary Study of Advanced Diagnostic Prescreening Methods," Energy Systems Laboratory, Mechanical Engineering Department, Texas A&M University, College Station, TX.

Air distribution is primarily through single duct multizone systems providing cooling temperatures of approximately 75 °F, and heating temperatures within the range of 70 to 72°F. Heating and air handling systems are turned off completely during the night and are controlled from a central location through a Carrier EMCS.

The school is operated from the middle of August through the middle of May, with approximately 1,529 students and 145 faculty and staff. The maximum school occupancy is from about 8:00 a.m. until 4:00 p.m.; however, the building is occupied for much longer periods, including weekends and summers. Stroman and Victoria High School alternate as the primary location for summer school. Stroman was the site during the summer of 1993. School district calendars for the reporting period of June 5, 1991, through June 4, 1994, are included in Tab A-1.

Large quartz lamps are used to light the tennis courts. These are shut off at 11:00 p.m. Electricity is purchased from Central Power and Light Company, and natural gas from ENTEX Gas Company.

A.2 EMCS Retrofit

The energy audit for Stroman High School determined that the HVAC operation was controlled manually, which resulted in excessive operating hours in each of the schools within the school district. Timeclock controls were installed many years ago, but were not suited for the needs of the school. See Tab A-2 for the full text technical analysis of the facility that was provided in the audit.

The proposed EMCS retrofit called for the installation of a direct digital control-based EMCS, which would control all HVAC equipment, measure exterior and interior space temperatures, and measure humidity in one or two critical locations within the school. The EMCS would have no override timers that custodial staffs could activate. Operating hours of all HVAC units would be determined by the maintenance staff, and controlled by that staff from its central headquarters via modem.

The EMCS system was installed and activated on January 31, 1992. It controls the HVAC equipment and some lights and measures the temperature and humidity at select locations. Although there are override capabilities, they are not used.

A.3 Analysis

A.3.1 Snapshot of consumption for September 1991-December 1993

Figures A-1 and A-2 represent monthly average consumption and peak consumption versus min-max average monthly temperature and peak temperature, respectively.[2]. Min-max average monthly temperature is calculated by averaging the maximum and minimum temperature each day to obtain min-max average daily temperature. The daily temperatures are then averaged over all days in each month to obtain min-max average monthly temperature.

The data points reflecting high temperature and low consumption are indicative of non-semester consumption. If those data points are ignored, there is a general increase of consumption with temperature, indicating a temperature dependence of consumption. Additionally, the post-retrofit data points are generally lower than the pre-retrofit data points. When compared to similar plots for other Texas schools in the LoanSTAR program, this site is a low energy use school. The reader is referred to the referenced report for a more detailed discussion of these plots.

[2] Landman, D.S., 1995. "Preliminary Study of Advanced Diagnostic Prescreening Methods," Energy Systems Laboratory, Mechanical Engineering Department, Texas A&M University, College Station, TX.

Figure A-1: *Monthly Average Consumption:* Consumption, in W/sf, versus min-max average monthly temperature, in °F for September 1991 - December 1993 (Stroman High School)

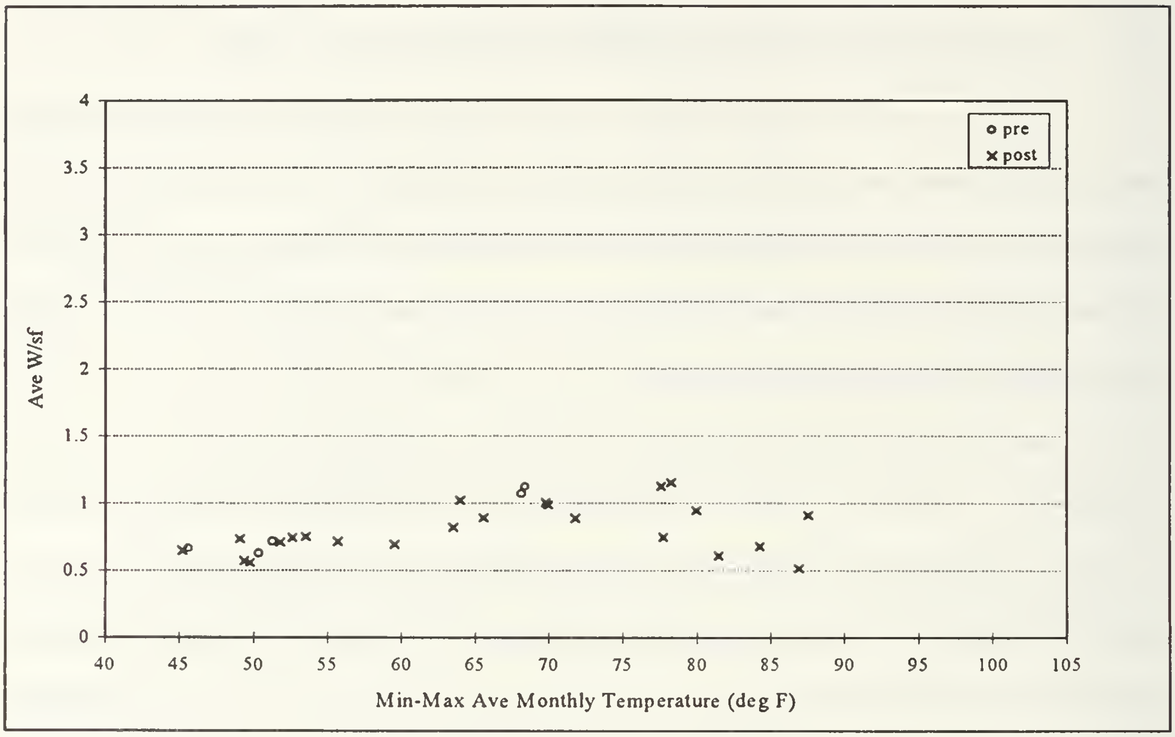
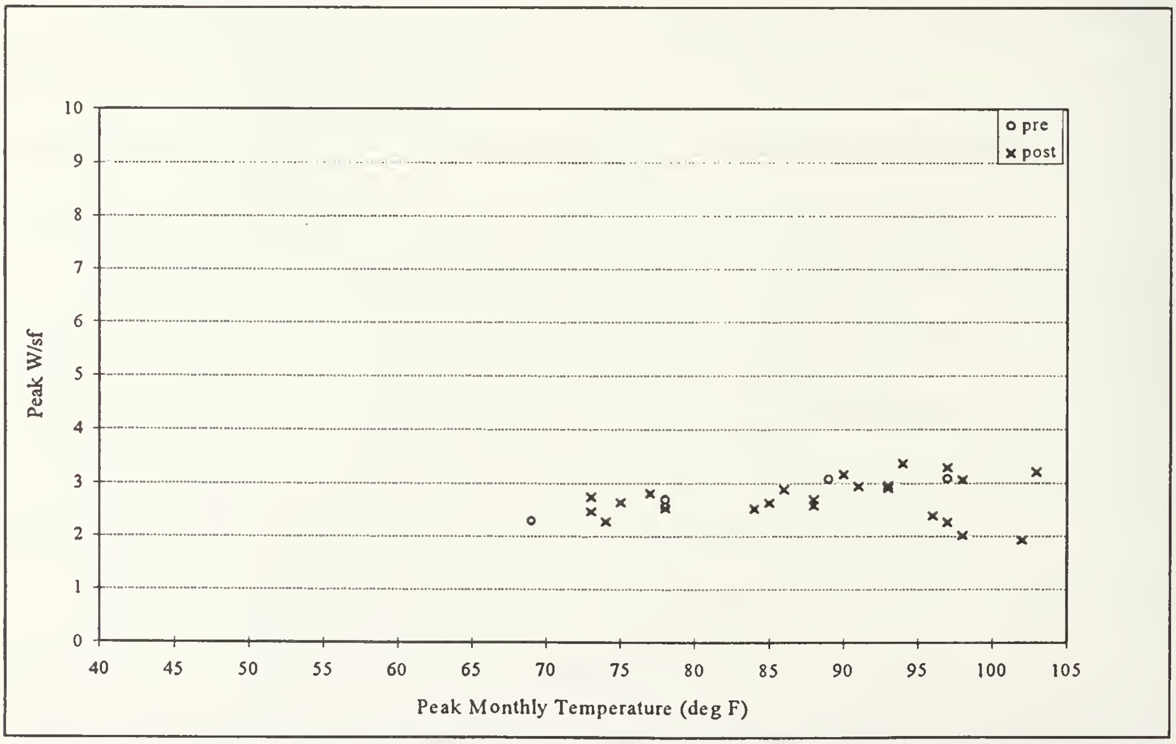


Figure A-2: *Monthly Peak Consumption:* Consumption, in W/sf, versus peak monthly temperatures, in °F, for September 1991 through December 1993 (Stroman High School)



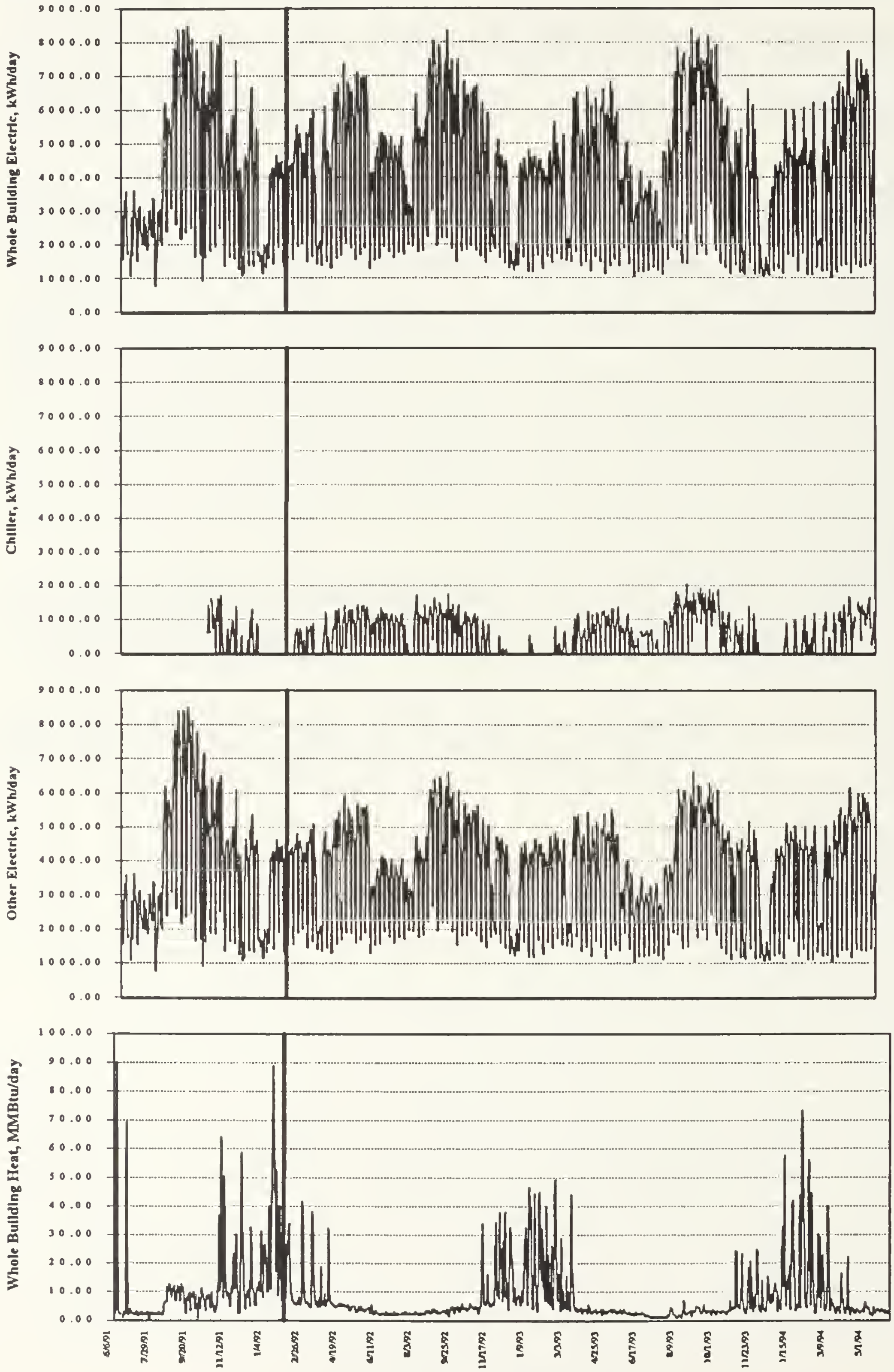
A.3.2 Timeline plots

Plots of energy consumption for the reporting period are shown in Figure A-3. The EMCS retrofit date of January 31, 1992, is shown by a vertical, bold line. Monitoring diagrams are provided in Tab A-3.

In looking at the whole building electric plot, there is no apparent decrease in consumption at any point along the timeline. There was an absorption chiller installed as a concurrent retrofit at this site. This resulted in the appearance of chiller consumption in September 1991. Any possible decrease in consumption due to the EMCS may have been offset by the increase in consumption due to the new chiller. The appropriate plot to analyze to look at effects due to EMCS only is the "other electric" plot, which is whole building electric minus the absorption chiller. Here a drop in consumption is evident between the pre-retrofit and post-retrofit time periods

The plot of whole building heat shows seasonal heating between November and April of each year. There is also a decrease in consumption evident between the pre-retrofit and post-retrofit periods.

Figure A-3: ***Energy Consumption time series*** **for June 1991 to June 1994 (Stroman High School)**



A.3.3 Whole Building Electricity Consumption (Post Period)

Table A-1 shows energy consumption for the post-retrofit period (February 1, 1992, through June 4, 1994), broken down by semester and non-semester. Whole building electricity consumption is broken down into two components: chiller electricity consumption and other electricity consumption. The post-retrofit period is used because there is significantly more data available in the that period, and it represents current usage.

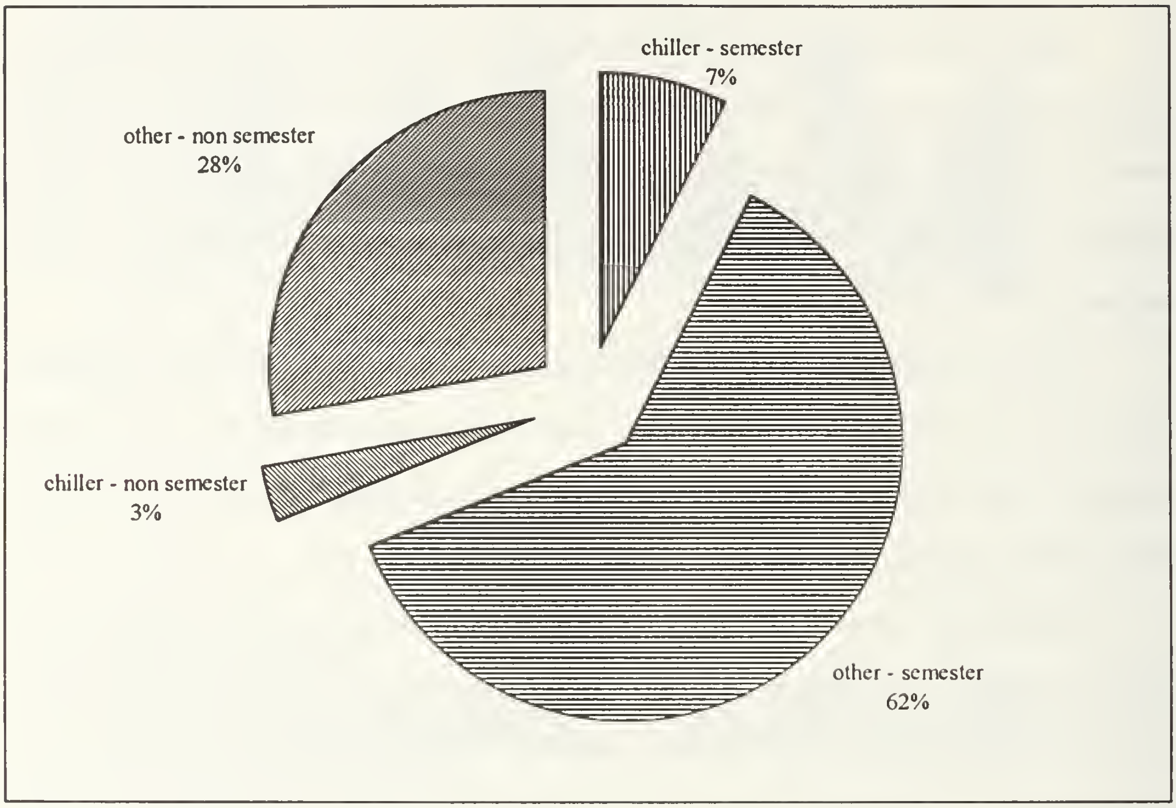
Figure A-4 graphically shows whole building electricity consumption for the post-retrofit period. For the semester period, 62% of whole building electric energy use is attributable to other electric equipment, while 7% is due to the electric chiller. For the non-semester period, other electric accounts for 28% of whole building electric energy, while the chiller accounts for 3%.

For both Table A-1 and Figure A-4, it is readily apparent that chiller consumption accounts for a small portion of the whole building electricity usage. Therefore, attention for reducing energy usage should be focused on the other electricity usage. This is also the reason for focusing attention on other electric consumption in this report. In this case, other electricity consumption is mainly roof-top HVAC units and lighting.

Table A-1: ***Energy Consumption*** **for post period, February 1992 - June 1994 (Stroman High School)**

	SEMESTER		NON-SEMESTER		TOTAL	
	ENERGY	$	ENERGY	$	ENERGY	$
wbelec, kWh	2,209,234	$61,593	952,917	$26,567	3,162,150	$88,161
chlr, kWh	236,828	$6,603	119,815	$3,340	356,643	$9,943
other, kWh	1,972,405	$54,991	833,102	$23,227	2,805,507	$78,218
wbheat, MMBtu	5,059	$24,028	1,352	$6,421	64,10	$30,449

Figure A-4: ***Whole Building Electricity Consumption*** **for post period, February 1992 - June 1994 Stroman High School**



A.3.4 Total Monthly Consumption

The total monthly energy consumption is summarized in Table A-2. Again, it is readily apparent that other electric accounts for the majority of this site's electric energy use.

Table A-2: ***Monthly Energy Consumption*** **(Stroman High School)**

	wbelec kWh/month	chiller kWh/month	other kWh/month	wbheat MMBtu/month
PRE PERIOD				
Jun 91	167,040	0	167,040	216
Jul	181,199	24,422	156,777	437
Aug	135,033	6,361	128,672	783
Sep	120,760	7,331	113,429	398
Oct	140,339	16,726	123,613	274
Nov	172,213	29,039	143,174	110
Dec	161,017	22,728	138,289	171
Jan 92	130,095	6,118	123,977	571
Total Consumption	1,207,697	112,726	1,094,971	2,960
Total Cost	$33,671	$3,143	$30,528	$14,059
POST PERIOD				
Feb 92	123,864	999	122,865	700
Mar	155,836	16,837	138,999	222
Apr	178,822	32,459	146,363	104
May	216,629	45,963	170,666	111
Jun	145,812	13,999	131,813	287
Jul	139,191	5,025	134,166	862
Aug	150,833	13,930	136,903	400
Sep	193,871	34,960	158,912	107
Oct	85,113	7,833	77,280	210
Nov	107,539	11,146	96,393	450
Dec	126,965	16,559	110,405	183
Jan 93	59,302	770	58,532	217
Feb	61,654	6,893	54,761	133
Mar	48,803	2,534	46,269	164
Apr	73,353	1,936	71,418	396
May	111,118	0	111,118	82
Jun	113,650	2,348	111,301	406
Jul	125,016	22,649	102,366	101
Aug	124,743	20,660	104,082	72
Sep	125,745	18,271	107,474	199
Oct	103,438	14,459	88,979	120
Nov	98,266	11,325	86,941	52
Dec	164,686	33,704	130,982	105
Jan 94	75,544	5,414	70,130	253
Feb	57,468	43	57,425	149
Mar	83,609	8,992	74,617	129
Apr	64,819	4,018	60,802	154
May	47,334	2,034	45,300	112
Jun 94	8,492	896	7,596	11
Total Consumption	3,171,513	356,656	2,814,857	6,483
Total Cost	$88,422	$9,944	$78,478	$30,795
Grand Total Consumption	4,379,210	469,382	3,909,828	9,443
Grand Total Cost	$122,092	$13,086	$109,006	$44,854

A.3.5 Average Daily Consumption

Figures A-5a and A-5b depict the average daily consumption for the semester period and the non-semester period. From both plots, you can see that the consumption for the weekdays does not change in profile, but does decrease in magnitude.

For the semester period, Figure A-5a, the weekday consumption decreased substantially during the daytime hours, 7:00 a.m. to 5:00 p.m., and slightly decreased during the nighttime hours, 5:00 p.m. to 7:00 a.m. The weekend consumption decreased during the nighttime, but increased during the daytime hours. Why does the post-retrofit consumption exceed that of the pre-retrofit consumption for weekends? One possible explanation is that the setpoints on the new EMCS are such that the consumption is greater during the weekend than before the EMCS was installed. Another possible explanation may be due to many more data points in the post period, and periodic special events on the weekends. These two factors combined may result in higher weekend daytime consumption in the post period.

For the non-semester period, Figure A-5b, weekday consumption slightly decreased during the daytime hours and greatly decreased during the nighttime hours. Here, the weekend usage changed in a manner similar to that of the weekdays. The changes in both weekday and weekend consumption can be attributed to the EMCS retrofit.

Tab A-4 contains a summary of the hourly averages and the respective standard deviations and count of data points. The hourly averages are the data that is plotted in Figures A-5a and A-5b. For this site, the standard deviations are quite large. They do not vary much between the hours of 0 through 6, then jump to higher levels in hours 7 through 23. This should not be alarming, because the periods that the data were averaged over include wide ranges of temperatures. As was seen earlier, in Figures A-1 and A-2, the energy usage is temperature dependent. The count of data points represents the actual number of data points used to calculate the average, which corresponds to the amount of time that the equipment was actually operating.

Figure A-5a: *Semester Pre-/Post-retrofit Consumption* (Stroman High School)

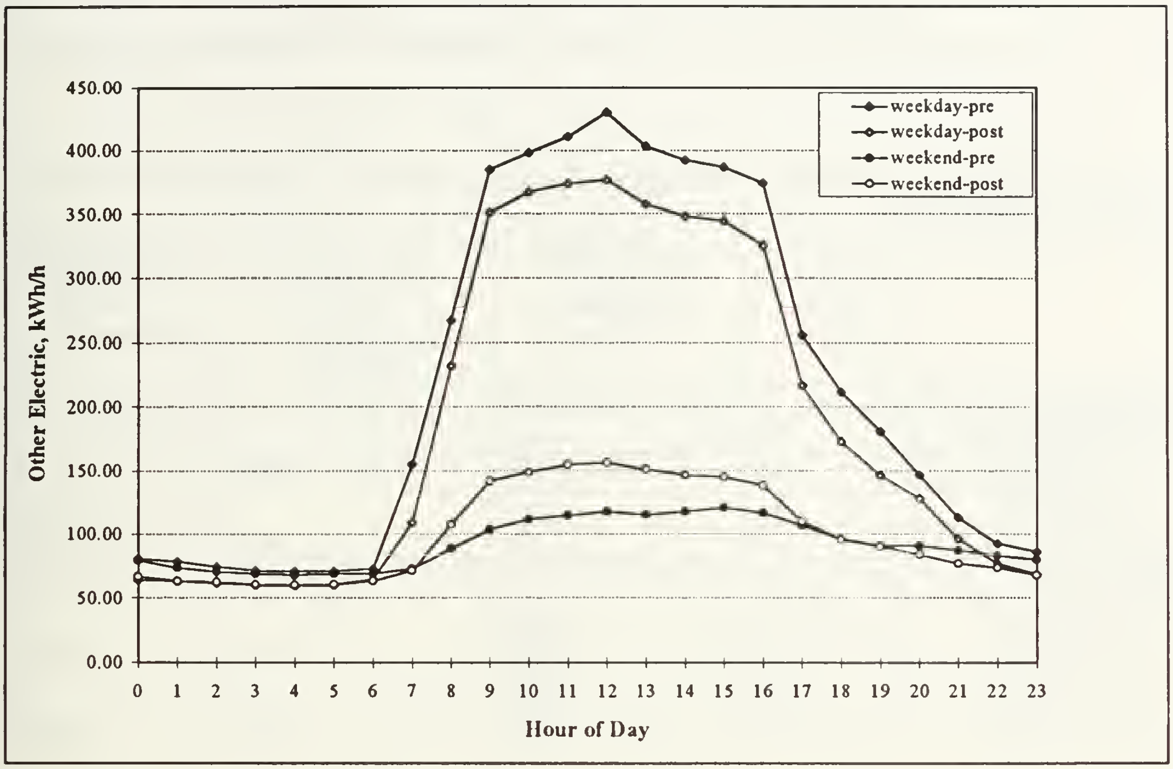
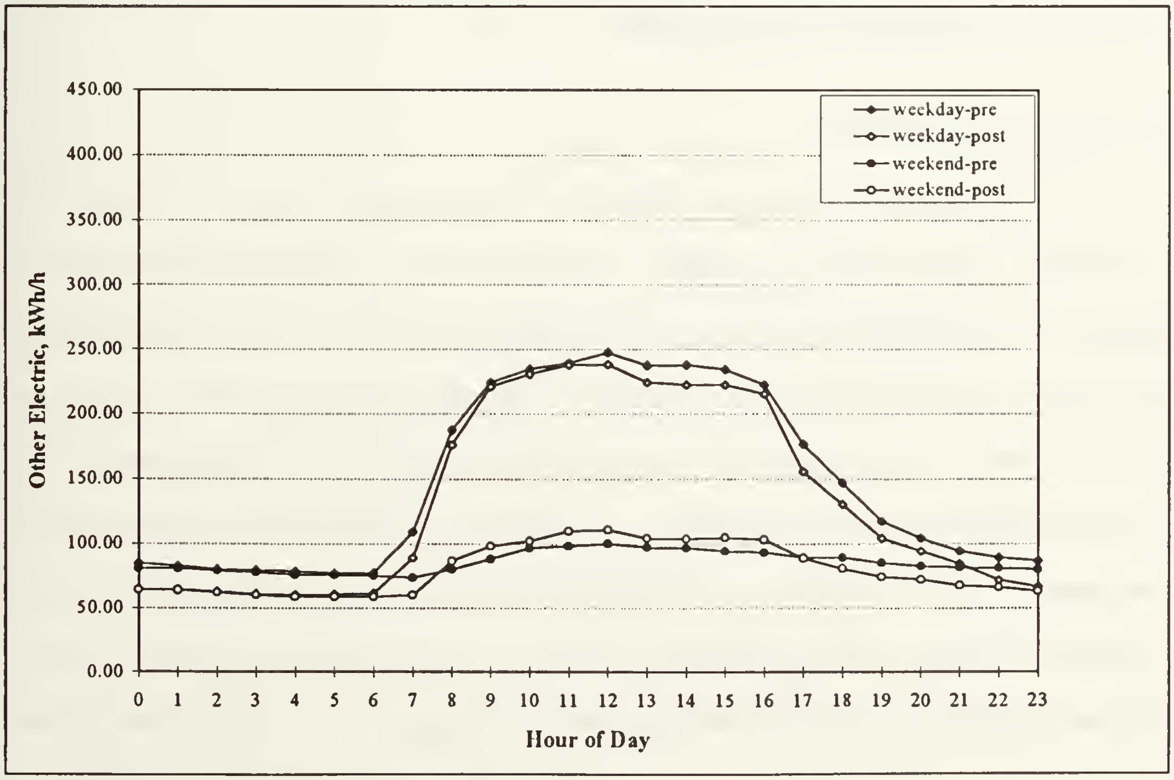


Figure A-5b: *Non-semester Pre-/Post-retrofit Comparison* (Stroman High School)



The difference in other electric energy consumption was calculated based on the average daily data. This is shown in Table A-3, both as a difference in energy and a percentage difference in energy.

Table A-3: ***Reduction in Other Electric Energy Consumption,*** **based on average daily data (Stroman High School)**

	# days in sort category	Average Daily Consumption kWh/day	Difference in Average Daily Consumption kWh/day	% Difference in Average Daily Consumption
Semester				
weekday-pre	91	5,210		
weekday-post	394	4,525	-685	-13.15%
weekend-pre	35	2,206		
weekend-post	149	2,395	189	8.57%
Non-semester				
weekday-pre	79	3,557		
weekday-post	241	3,225	-332	-9.33%
weekend-pre	33	2,060		
weekend-post	92	1,930	-130	-6.31%

There was a reduction in consumption for all categories except semester, weekend. Possible reasons for this increase were discussed in the previous section.

A.3.6 Plots from MECR

The September MECR energy use plots for four years are shown in Tab A-5. These provide a more qualitative look at the effects of the EMCS. September 1991 is a pre-retrofit plot. Note that there is generally low consumption between the hours of Midnight and 6:00 a.m., with a gradual increase to daytime levels. This is followed by a slow decrease in consumption between the hours of 4:00 p.m. and 10:00 p.m. There are many afternoons and evenings where consumption did not drop to nighttime levels. September 1992 shows a decreased nighttime consumption, with a much sharper slope up to daytime levels between 7:00 a.m. and 8:00 a.m. The consumption drops off much more quickly at 4:00 p.m., as compared to September 1991, indicating that the EMCS is controlling the consumption as expected. There are still a few days with high afternoon and evening consumption, most likely due to special events

that required the air conditioning and lighting to remain on after hours. The profiles continue to improve for the months of September 1993 and September 1994.

It should be noted that these profiles only allow a look at weekday data. The weekend data is unreadable from these plots. Separating the data into weekdays and weekends, then plotting separately, would enable one to evaluate weekends, as well as weekdays.

A.3.7 Data Summary Notebook Information

The Data Summary Notebook information is included in Tab A-6 for information only. It is not analyzed for this site

Tab A-1

School District Schedule

VICTORIA PUBLIC SCHOOLS
SCHOOL CALENDAR 1990 - 91

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
JULY	1	2	3		5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30	31					
AUGUST				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26							
SEPTEMBER	1 2		<4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30							19
OCTOBER		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15>	<16	17	18	19	20 21	22	23		25	26	27 28	29	30	31				23
NOVEMBER					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21			24 25	26>	<27	28	29	30		20
DECEMBER	1 2	3		5	6	7	8 9	10	11	12	13	14	15 16	17	18	19			22 23						29 30							13
JANUARY				2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21>		<23	24	25	26 27	28	29	30	31			21
FEBRUARY						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25		27	28			20
MARCH						1	2 3	4>	<5	6	7		9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24						30 31	15
APRIL		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15		17	18	19	20 21	22>	<23	24	25	26	27 28	29	30					22
MAY				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26		28	29	30	31>		22
JUNE	2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30							

Total Days 175

Inservice

August 27-31
January 22
March 8 - Optional Inservice
June 1

Bad Weather Days:

Instruction.........June 3; June 4
Inservice/Preparation...June 5

Holidays

July 4 - Independence Day
September 3-Labor Day
November 22-23 - Thanksgiving
December 20-31, Christmas
January 1 New Year
March 25-29 Spring Break
May 27 - Memorial Day

Reporting Periods

First Semester Begins ...September 4
First Semester Ends ......January 21

Second Semester Begins..January 23
Second Semester Ends...........May 31

No Appraisal Days

Sept. 4-14	Jan. 2, 14-18
Nov. 21	Mar. 22
Dec. 19	May 23-31

Early Dismissal

October 24
December 4
February 26
April 16
May 31

Graduation

Victoria H.S...........June1
Stroman H.S...........May 31

Six Weeks - Begins		Ends	
First..........	September 4	October 15	30
Second.......	October 16...	November 26	28
Third.........	November 27.	January 21	31
		1st Semester	89
Fourth.......	January 23...	March 4	29
Fifth..........	March 5..	April 22	29
Sixth.........	April 23........	May 31	28
		2nd Semester	86
		Total	175

VICTORIA PUBLIC SCHOOLS
SCHOOL CALENDAR 1991- 1992

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
1991 JULY		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30	31				
AUGUST					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21	<22	23	24 25	26	27	28	29	30	31	7
SEPTEMBER	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30						20
OCTOBER			1	2	3	4	5 6	7>	<8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30	31			23
NOVEMBER						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18>	<19	20	21	22	23 24	25	26	27	28	29	30	19
DECEMBER	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30	31					15
1992 JANUARY				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16>		18 19	<20	21	22	23	24	25 26	27	28	29	30	31		19
FEBRUARY	1 2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29							20
MARCH	1	2>	<3	4	5	6	7 8	9	10	11	12		14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30	31					16
APRIL				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16>	17	18 19	20	<21	22	23	24	25 26	27	28	29	30			20
MAY						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30 31	21
JUNE		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30					

TOTAL DAYS 180

Inservice/Preparation Dates
August 20-21
January 17
March 13 Effective Schools
May 30

Bad Weather Days:
April 20
June 1

Holidays
July 4 - Independence Day
September 2 - Labor Day
Nov. 27 (1/2)-29 - Thanksgiving
December 20 (1/2) January 3
Christmas, New Year
March 16-20 - Spring Break
April 17 - 20 Easter

Appraisal Periods
1st Appraisal Period (Level 1)
September 5-January 10
1st Appraisal Period (Level 2,3, 4)
September 5-May 20
2nd Appraisal Period (Level 1)
January 20-May 20

No Appraisal Days
Aug. 21-Sept. 4
Nov. 26
Dec. 20
Jan. 13-16
April 16
May 21-29

Early Dismissal
October 23
Nov.27 (Early Release Day)
Dec. 20 (Early Release Day)
April 28
May 29

Graduation
VHS....May 29
SHS....May 30

Six Weeks -	Begins	Ends	
First..........	August 22........	October 7	32
Second.......	October 8...	Nov. 18	30
Third........	November 19..	January 16	31
1st Semester	Aug. 22-Jan. 16		93
Fourth.......	January 20....	March 2	31
Fifth..........	March 3.........	April 16	27
Sixth.........	April 21.......	May 29	29
2nd Semester	Jan. 20-May 29		87
		Total	180

Revised June 20, 1991

SCHOOL CALENDAR 1992 - 93

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
1992 JULY				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28	29	30	31		
AUGUST	1 2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	< 19	20	21	22 23	24	25	26	27	28	29 30	31						9
SEPTEMBER			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28 >	< 29	30				21
OCTOBER					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21	22	23	24 25	26	27	28	29	30	31	22
NOVEMBER	1	2	3	4	5	6	7 8	9 >	< 10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30						19
DECEMBER			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18 >	19 20	21	22	23	24	25	26 27	28	29	30	31			14
1993 JANUARY						1	2 3	4	< 5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30 31	19
FEBRUARY		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16 >	< 17	18	19	20 21	22	23	24	25	26	27 28							19
MARCH		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30	31				18
APRIL					1	2	3 4	5	6	7	8 >	9	10 11	12	< 13	14	15	16	17 18	19	20	21	22	23	24 25	26	27	28	29	30		20
MAY	1 2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30	31						19
JUNE			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30				

Total Days 180

Inservice
August 17-18
January 4
Feb. 15 Effective Schools
May 28

Bad Weather Days
April 12
May 29

Holidays
July 4 - Independence Day
September 7 - Labor Day
November 25(1/2)-27
Thanksgiving
December 18(1/2)-January 1
Christmas, New Year
March 15-19 - Spring Break
April 9-12 - Easter

Appraisal Period
1st Appraisal Period (Level 1)
September 2 - January 8
1st Appraisal Period (Level 2,3,4)
September 2 - May 21
2nd Appraisal Period (Level 1)
January 11 - May 21

No Appraisal Days *
August 19 - September 1
November 24
December 14 - 17
April 8
May 3 - 27
(except for 3rd appraisals)

Early Dismissal
September 15
October 12
November 25
(Early Release Day)
December 18
(Early Release Day)
April 28
May 27

Graduation
SHS.....May 27
VHS.....May 28

Six Weeks - Begins		Ends	
First..........	Aug. 19	Sept. 28	28
Second.......	Sept. 29	Nov. 9	30
Third.........	Nov. 10	Dec. 18	27
1st Semester			
August 19 - December 18			85
Fourth.....	Jan. 5	Feb. 16	30
Fifth........	Feb. 17	Apr. 8	32
Sixth.......	Apr. 13	May 27	33
2nd Semester			
January 5 - May 28			95
		TOTAL	180

*Revised 6-92

VICTORIA PUBLIC SCHOOLS
School Calendar 1993-1994

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
1993 JULY					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21	22	23	24 25	26	27	28	29	30	31	
AUGUST	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	<18	19	20	21 22	23	24	25	26	27	28 29	30	31					10
SEPTEMBER				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28>	<29	30			19
OCTOBER						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30 31	21
NOVEMBER		1	2	3	4>	<5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30					19
DECEMBER				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28	29	30	31		13
1994 JANUARY	1 2	3	4	5	<6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30	31						18
FEBRUARY			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17>	<18	19 20	21	22	23	24	25	26 27	28						19
MARCH			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30	31			17
APRIL						1	2 3	4	5	6	7	8	9 10	11	12	13	14>	<15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30	19
MAY	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27>	28 29	30	31					20
JUNE				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28	29	30			
																															Total	175

Inservice
September 7-8
January 4-5
February 21
March 11

Workdays
August 16-17
January 3
May 28

Holidays
July 5 – Holiday
September 6 – Labor Day
November 11 – Veteran's Day
November 24 (1/2)-26 Thanksgiving
December 17 (1/2)-31 Christmas
March 14-18 – Spring Break
April 1-4 – Easter

Bad Weather Days
April 4
May 28

Appraisal Period
1st Appraisal Period (Level 1) September 1 - January 21
1st Appraisal Period (Level 2, 3, 4) September 1 - May 6
2nd Appraisal Period (Level 1) January 24 - May 6

No Appraisal Days
August 18-31
September 3
November 10
November 23-24
December 16-17
March 10, 31
May 9-27

Early Dismissal
November 24 (Early Release Day)
December 17 (Early Release Day)

Graduation

Victoria High School	May 26
Stroman High School	May 27

Six Weeks	Begins <	Ends >	
First	August 18	September 28	27
Second	September 29	November 4	27
Third	November 5	December 17	28
1st Semester	August 18 - December 17		82
Fourth	January 6	February 17	31
Fifth	February 18	April 14	31
Sixth	April 15	May 27	31
2nd Semester	January 6 - May 27		93
		TOTAL	175

Tab A-2

Audit Technical Analysis

ECRM DESCRIPTIONS AND CALCULATIONS

Facility Name: All Schools

ECRM No.: 1

ECRM Name: Energy Management System

a. Summary

Kwh savings:	1,583,682	Kwh/yr
Demand savings:	898	KW-mo/yr
MCF savings:	3,850	MCF/yr
Cost savings:	$95,254	/yr
Implementation cost:	$380,980	
Simple payback:	4.0	years

b. Description

On/Off and temperature control in all of the Victoria ISD schools addressed in this report are inadequate. Typically, on/off controls consist of a) 7-day timeclocks which are controlled manually, b) manual control at thermostats or wall switches, and c) programmable thermostats in a very few locations, installed in the last two years. The great majority of on/off control is performed manually, with the result that operating hours are excessive in every school. There is not a single school addressed in this report where on/off control for the majority of HVAC equipment is performed automatically.

Timeclock controls were installed many years ago and are not suited for the needs of the schools.

- There is no way to enforce rigorous hours of HVAC operation if the custodial staff has access to all timeclocks. Even if the timeclocks were functioning with their trippers and the timeclock cabinet were locked, override timers on the face of the timeclock cabinets would allow custodians to turn on HVAC units. The custodians work typically until 9 PM. The natural human tendency is to keep the units on to maintain most comfortable working conditions. Custodial staffs have been instructed on several occasions by the VISD maintenance staff to turn off HVAC promptly after school. Without direct and continuous supervision, one cannot reasonably expect the custodial staff to do so. And they don't.
- The timeclocks offer little flexibility. They typically control multiple HVAC units on one circuit. Often, an entire bank of HVAC units operates when in fact not all are needed. Special events may at time be held outside of normal operating hours. The existing override timers also control banks of units, so -- if the timeclocks and override timers were even used -- more units would operate than necessary.
- There is no feedback with the timeclock system, such as space temperature or humidity readings, and actual operating status of the unit. In several cases, air conditioning takes place 24 hours per day in order to prevent humidity-related problems. Also, heating units may be left on overnight when weather is cold, maintaining temperatures at comfort conditions. Feedback information on space versus outdoor conditions could save a great deal of energy by reducing operating hours.

Summer operation of HVAC systems is also excessive. Schools are cleaned over a period of several weeks during each summer. Depending upon school size, the number of people cleaning, whether summer school is held or not, and the type of cleaning projects taking place, the cleaning process can take up to 6 weeks or more. Often the cleaning crews will turn on air conditioning for entire schools or wings of schools, regardless of how many rooms are actually being cleaned, since the method of turning units on is to flip a master timeclock switch which turns on whole banks of units. Again, virtually all control is manual through thermostats or timeclock master trippers. In addition to air conditioning schools for personal comfort, the cleaning crew operates the air conditioning to speed up drying of floors and other surfaces cleaned. Also, some teachers start coming to school by mid August. Typically, air conditioning throughout an entire school is again turned on, even though the number of teachers occupying the school is very small.

Temperature controls are virtually all open to occupant adjustment. The number of locking thermostats in all schools addressed in this report can be counted on one hand, and some of those are not locked. Typical settings are in the low 70's (deg F).

Even the programmable thermostats of the most recently installed HVAC units offer less than ideal control. The units inspected were programmed for 6 AM to 6 PM operation. While this schedule covers most occupancy demands, it is generally excessive. Neither teachers nor staff reprogram the thermostats as their occupancy needs differ.

Though the quantity of timeclocks and HVAC units may vary by school, the control methodology described above is typical of all the schools in this report. Controls in each school are addressed individually below. A summary of On/Off times follows (as determined by interviews with custodial staffs), starting on page 80.

Aloe Elementary

There are four timeclocks located in a small janitorial room in the main wing. Each is a 7-day timeclock. Clock #1 controls the library unit, #2 the kitchen, #3 the offices and classrooms, and #4 the cafeteria units. There are override toggle switches in the face of the timeclock cabinet, one for each timeclock. However, as the timeclocks are not used as originally intended, the overrides are useless. On each timeclock, on/off trippers have been removed, and the custodial staff uses the master on/off tripper to control units. All units are turned on manually by custodians at about 6:30 - 7:00 AM. The custodial staff works after school until 9 PM, and turns the units off when they leave.

In the 3rd/4th grade wing and the kindergarten wing, programmable thermostats have been installed. On/off times are 6 AM to 6 PM, Monday through Friday.

De Leon Elementary

There are two timeclock stations in the school. The first station, located behind the library, has four 7-day timeclocks. The second station, located in an electrical room in the south classroom wing, has three 7-day timeclocks. There is an override toggle switch for each timeclock. These seven timeclocks control the seven rooftop HVAC units installed with the original school. HVAC units 8 - 11 were added with the new classroom addition. They are controlled directly from individual room thermostats, not by timeclock.

All units are controlled manually by the custodial staff using the timeclock master on/off tripper, and room thermostats. Operating hours are from 6 AM until 8 PM.

Dudley Elementary

There are three 7-day timeclocks located in the electrical room across the hall from the cafeteria. The first controls classroom and office units, the second the kitchen, and the third the cafeteria. All units are controlled manually by the custodial staff using the timeclock master on/off tripper. On/off hours are typically 7 AM to 7 PM, Monday through Friday.

Hopkins Elementary

There are four rooms which contain timeclocks at Hopkins. The main mechanical room has four 7-day timeclocks, controlling direct expansion units for 1) the office area, 2) the library, 3) the kitchen, and 4) the cafeteria. There is a single 7-day timeclock in the north wing, one in the south wing, and one in the middle wing. Each controls HVAC fan-coil units and chillers/pump for their respective wing. Most or all trippers have been removed from all timeclocks, and all are operated manually.

All units are turned on manually by custodians at about 6:00 AM. The custodial staff works after school until 9 PM, and turns the units off when they leave.

Howell Intermediate

There is a main control panel at Howell Intermediate located in the main mechanical room. Toggle switches are located in the face of the panel for controlling virtually all HVAC units in the school. When the custodian arrives at 6:30 AM, he turns on all HVAC units via the toggle switches, and the chiller if necessary. He always turns on the boiler, no matter what the weather conditions, since the HVAC system at Howell is reheat. Another custodian turns off HVAC equipment around 7 PM.

In summer, the same procedure is followed for the approximately six weeks cleaning period.

Juan Linn Elementary

All HVAC units installed with the 1986 addition are controlled by programmable thermostats. Programmed on/off times are 6 AM on, and 6 PM off, Monday through Friday. The one exception is the library unit. It has a programmable thermostat, but the unit remains in operation continuously out of concern for mildew on library books. The two rooftop units over the original (east) classroom wing have been replaced recently, and are controlled by programmable thermostats also.

All fan-coil units and the chiller of the stand-alone 1951 addition are controlled by 7-day timeclock located by the east entrance to the building. All trippers to the clock have been removed. The janitor operates the master timeclock tripper to control HVAC.

In the main building, the custodian turns units on manually at the thermostats when she arrives at 6:45 AM, and another custodian turns units off around 8 PM.

Summer school is held in Juan Linn for six weeks. Again, custodians turn equipment on/off manually. However, most units are turned off earlier in the day as compared to the regular school year.

O'Connor Elementary

Two rooms contain 7-day timeclocks at O'Connor, one in the north wing and one in the south. All units are turned on manually by custodians at about 6:30 AM, and off at around 8:00 PM. The east wing addition units are controlled manually by custodians via their thermostats.

There are two locking thermostats in the north wing, but neither was locked when seen.

Shields Elementary

The majority of floor area in Shields is served by hydronic fan-coil units. Control is the same as in all other elementaries: 7-day timeclocks exist, but custodial staff uses only the master trippers to turn units on and off when they arrive and depart. Units are turned on around 7 AM, and off about 6:30 PM.

Stanly Elementary

Control of HVAC units in Stanly is identical to O'Connor. The two schools originally had identical floor and HVAC plans. Timeclocks are located in exactly the same rooms as in O'Connor.

Stroman High School

Control of HVAC units at Stroman requires very intensive footwork. The custodian makes rounds to every air handling unit, most fan-coil units, many direct expansion units, and the chiller/boiler/auxiliary equipment each morning around 6:45 AM, where he turns equipment on. Another custodian makes a similar round at about 8:30 PM to turn equipment off.

The kitchen staff turns kitchen HVAC on and off. The coaching staff turns athletic building HVAC off, and the custodial staff turns it back on in the morning, though often the coaching staff forgets to turn units off.

A small (46 ton) reciprocating chiller is located adjacent to the four story Unit A. This chiller is piped to serve only Unit A. During summer and after school hours, parts of Unit A (which contains administrative offices) are the only occupied portions of the school. At 4:30 PM during the school year, the absorption chiller is shut down and the reciprocating chiller is turned on, and continues to operate until 9 PM. In summer, the reciprocating chiller is turned on 7:00 AM, and off at 6:00 PM, unless the main chiller is operating.

Direct expansion split systems serving the Band hall are thermostatically controlled, but are left in operation continuously, summer and winter. If the main air handler serving Band has been shut off and indoor temperature starts to rise, the DX units will maintain humidity and temperature conditions. These backup DX units were installed out of concern for humidity-related problems with Band instruments.

Summer cleaning of the high school takes about 5 to 6 weeks. During this time, the main absorption chiller operates every day, and virtually the entire school is cooled. Cleaning is finished by mid- to late-July, and only the reciprocating chiller operates after that.

Victoria High School

Victoria High is another school requiring intensive footwork in turning HVAC systems on and off. The VHS campus contains numerous buildings spread out over a wide geographical area. The maintenance man starts his round at 7 AM to all mechanical rooms and thermostats/wall switches, turning on equipment. As at Stroman, the coaching staff is responsible for turning off some athletic building HVAC equipment (though they often forget) and the maintenance man turns it back on in the morning.

There are two rooftop units over the Learning Resource Center. During the regular school year, these operate from 7:15 AM until 4 PM. During summer, one of the units is shut down, but the other remains in operation 24 hours per day to prevent problems with mildew. Starting in September, HVAC for the boys dressing room is left on continuously until cold weather hits, so as to reduce odor problems which are worsened by heat and humidity.

Summer school is held in the Academic Wing of VHS, and occasionally in the main wing. The Academic Wing is served by the absorption chiller. The chiller is turned on at 6:30 AM, and off at 1:30 PM. The fan-coil units served by the chiller remain in operation continuously, both summer and winter. The on/off switches for them are located inside the units.

Fan-coil units for the main building are controlled by toggle switches mounted on the wall of each classroom. Teachers are supposed to turn these units off as they leave each day, and the maintenance staff turns them back on in the morning. However, as often as not, the fan-coil units are left on at night.

This ECRM calls for the installation of a direct digital control-based energy management system (EMS) for each school addressed in this report. The EMS will control all HVAC equipment, measure exterior and interior space temperatures, and measure humidity in one or two critical locations within each school. The EMS will have no override timers that custodial staffs can activate. Operating hours of all HVAC units will be determined by the maintenance staff, and controlled by that staff from its central headquarters via modem. (Floor plans on pages 27 through 37 show locations of the units to be controlled, and the proposed locations of new DDC controllers).

Tab A-3

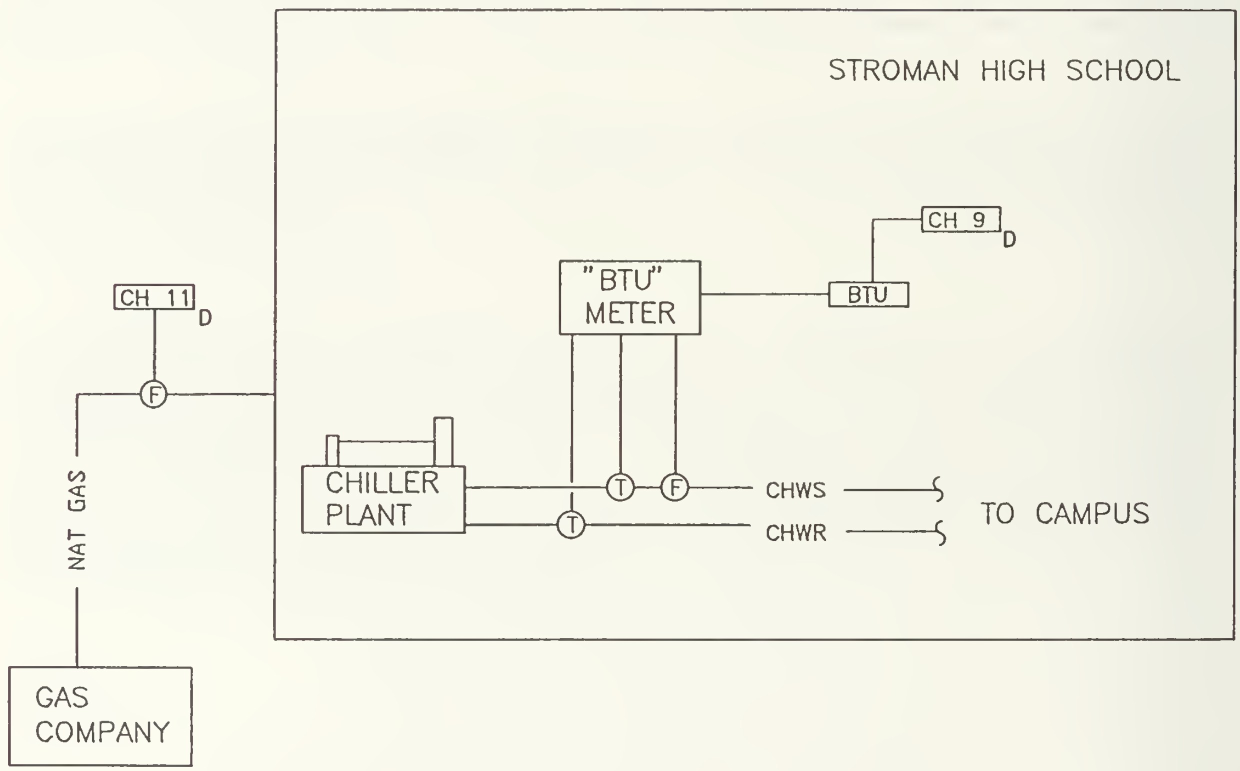
Monitoring Diagrams

THERMAL MONITORING DIAGRAM

VISD – STROMAN HS

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



VISD/STROMAN HS – SITE 126

Tab A-4

Average Hourly Data & Related Statistics

Hourly Averages

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	80.6011	78.0633	74.0433	71.1233	70.8833	70.8022	72.5367	155.2256	267.5822	384.9000	398.2044	411.1200	430.2467	403.8189	392.5822	387.1378	374.1811	255.8758	211.8505	180.9022	146.8330	113.0824	92.5396	85.8571
1-B-S	64.1596	63.1154	61.6433	60.1218	59.5119	60.0570	64.6301	108.8884	231.9041	351.1770	367.3906	373.8428	376.8638	357.4618	348.1329	344.8428	325.7368	216.7218	173.4122	146.4762	128.0020	95.9694	76.7127	68.1843
0-A-S	78.9333	73.3833	70.3167	68.4194	67.8028	68.3528	68.5389	72.6417	88.1611	103.7972	111.5528	114.4694	117.5639	115.2528	117.5611	120.5500	116.4500	106.5056	95.9083	90.2139	90.3583	86.6972	82.5778	79.7972
0-B-S	66.5747	63.3799	62.2280	60.4800	60.0933	60.5607	63.0227	71.1180	107.7053	142.1427	148.7100	155.0487	156.7340	151.0147	146.6233	144.9127	138.0960	110.2160	95.2000	89.9687	83.7280	76.8107	73.2980	67.4567
1-A-NS	85.1342	83.0763	80.4013	79.9724	78.7816	77.5053	78.2895	109.5289	187.6539	224.4080	235.1095	239.2440	247.8920	237.6987	238.1434	234.3675	222.6675	176.9792	147.2338	117.2662	104.6844	94.7065	89.8286	86.8545
1-B-NS	65.0865	64.2107	62.8326	61.1819	60.2935	60.8437	62.0144	89.6791	176.4423	220.9595	230.6405	237.9753	238.3265	224.7019	222.6851	222.2614	215.5260	155.6721	130.5860	104.7237	94.4340	85.1660	71.7665	66.8981
0-A-NS	80.9794	80.8176	79.5794	77.8824	75.8559	76.1265	75.3559	73.8912	80.2853	88.5794	97.1147	98.6029	100.7059	97.1588	97.0118	94.6206	93.7235	89.3912	89.7735	85.3735	83.0324	82.0471	81.6118	80.5765
0-B-NS	64.4796	64.0624	62.2215	60.0720	58.8656	59.0548	59.0452	60.6452	86.8086	98.3871	102.5828	110.1043	111.0613	104.6613	103.9161	104.8269	103.6194	89.1430	81.0548	74.6419	72.3656	68.2086	66.3848	63.6946

Standard Deviation of Hourly Averages

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	25.3410	24.5628	23.9807	23.6660	23.9456	23.4802	24.9052	100.0932	141.2379	180.3954	183.4821	185.3354	193.8659	181.9761	178.2780	171.9746	165.1374	113.1544	90.6599	75.8714	65.3395	51.6266	32.7669	28.6587
1-B-S	16.9846	16.0338	16.2044	15.9703	15.8685	15.2908	15.8143	43.3088	98.8716	147.7952	151.0817	154.3809	157.2386	146.0023	143.0841	141.9651	132.6919	80.9606	60.0906	51.3174	42.9628	32.4450	23.8272	18.7570
0-A-S	5.0023	5.1525	6.9990	4.2755	4.3433	4.3066	9.7434	21.2865	65.4293	118.6169	127.6811	127.3434	128.2437	122.2285	118.2886	115.2279	108.9561	67.8297	57.0291	42.1453	35.4515	16.4755	8.2720	5.3669
0-B-S	9.2759	7.0121	8.1867	7.2048	6.5885	8.3277	15.3085	41.2448	91.8113	141.4267	149.8942	148.7512	149.2720	140.5707	134.9211	134.3449	125.9359	73.0636	59.0526	49.0909	46.9723	37.5807	19.9797	13.8514
1-A-NS	6.4345	5.4261	5.6430	5.5277	5.3563	10.3032	11.8481	30.9575	84.5955	138.5149	144.9874	145.8488	145.4274	137.6667	128.9166	129.3831	118.6730	74.1428	59.4598	47.1399	40.7147	29.4638	20.1145	13.1435
1-B-NS	11.2263	9.8791	9.3756	9.0758	8.8135	9.1657	8.8091	36.8922	100.0480	142.8922	143.8453	146.9212	146.8342	138.4398	133.9863	134.4776	128.0702	78.4337	62.5079	48.5720	41.1901	33.8299	18.4692	12.5877
0-A-NS	6.3878	3.0515	4.7082	4.3656	4.1897	5.0384	5.4141	19.7933	57.5177	73.9479	83.8130	89.9791	91.3395	85.2871	76.1813	70.7657	66.9877	47.0584	31.2224	19.0053	16.2480	16.0963	11.3177	5.8065
0-B-NS	12.0600	15.1783	14.4982	11.7996	11.1014	10.8808	13.4575	45.7692	102.3336	136.4169	143.2010	142.8401	141.8253	133.9656	132.5129	134.7850	131.6408	81.7059	70.6250	50.0812	39.3718	29.7149	15.3570	10.8284

Count of Data Points

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	91	91	91	91	91	91	91
1-B-S	394	395	395	395	395	395	395	395	395	395	395	395	395	395	395	395	394	395	395	395	395	395	395	395
0-A-S	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
0-B-S	226	225	226	226	226	226	226	226	226	225	224	225	225	225	226	227	227	227	227	227	227	227	227	227
1-A-NS	76	76	76	76	76	76	76	76	76	75	74	75	75	75	76	77	77	77	77	77	77	77	77	77
1-B-NS	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215
0-A-NS	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
0-B-NS	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	93	92	93

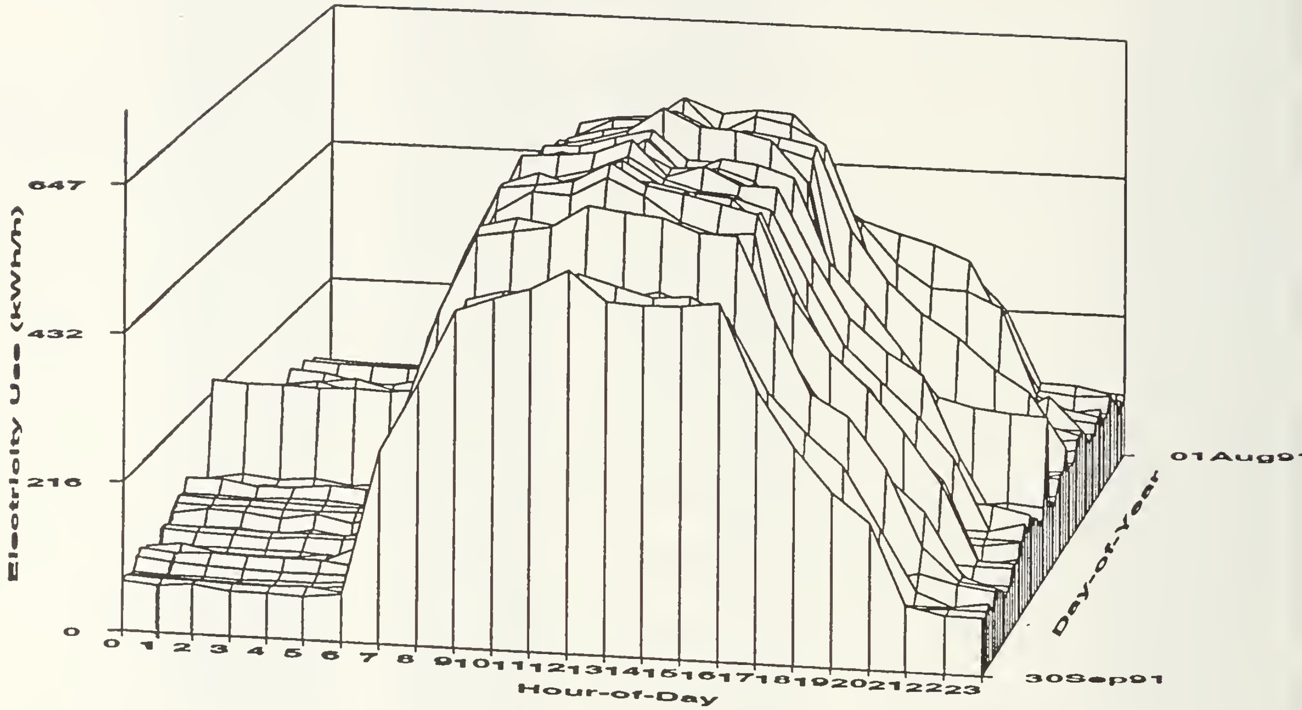
Key

1-A-S	=	Semester/Weekday/Pre-Retrofit
1-B-S	=	Semester/Weekday/Post-Retrofit
0-A-S	=	Semester/Weekend/Pre-Retrofit
0-B-S	=	Semester/Weekend/Post-Retrofit
1-A-NS	=	Non-Semester/Weekday/Pre-Retrofit
1-B-NS	=	Non-Semester/Weekday/Post-Retrofit
0-A-NS	=	Non-Semester/Weekend/Pre-Retrofit
0-B-NS	=	Non-Semester/Weekend/Post-Retrofit

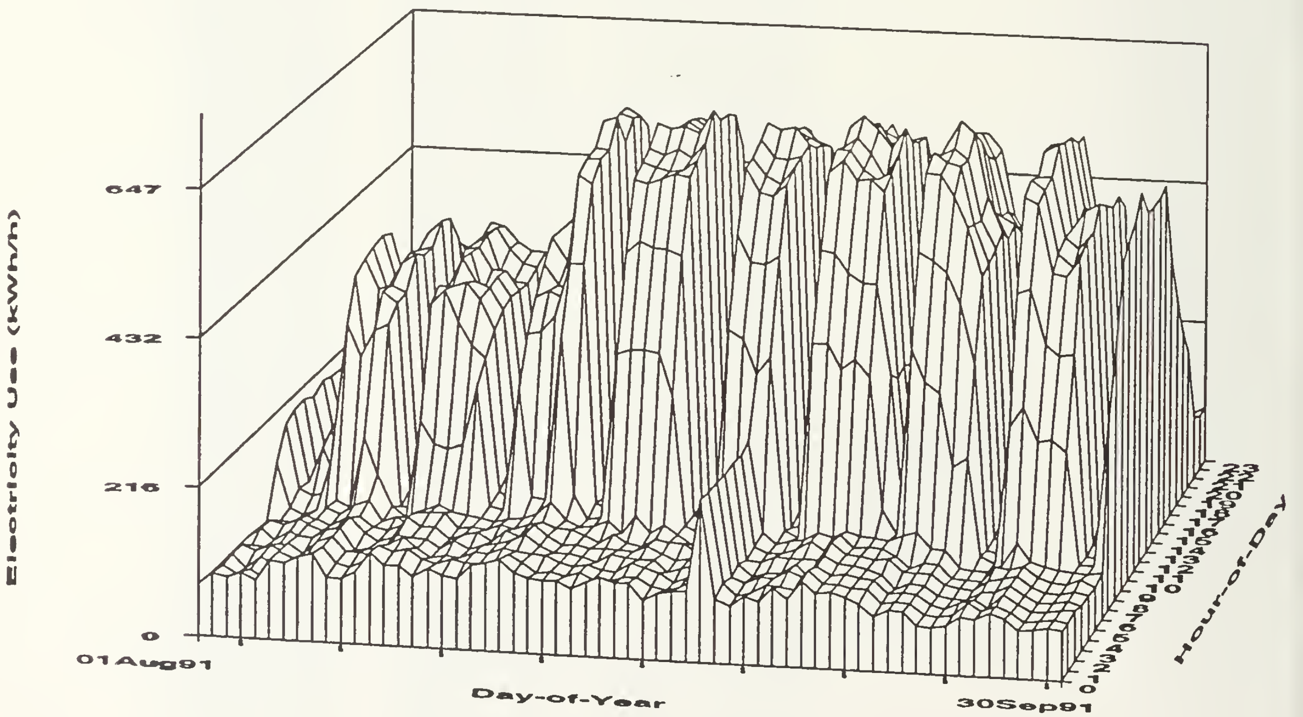
Tab A-5

MECR Plots

Whole–Building Electric



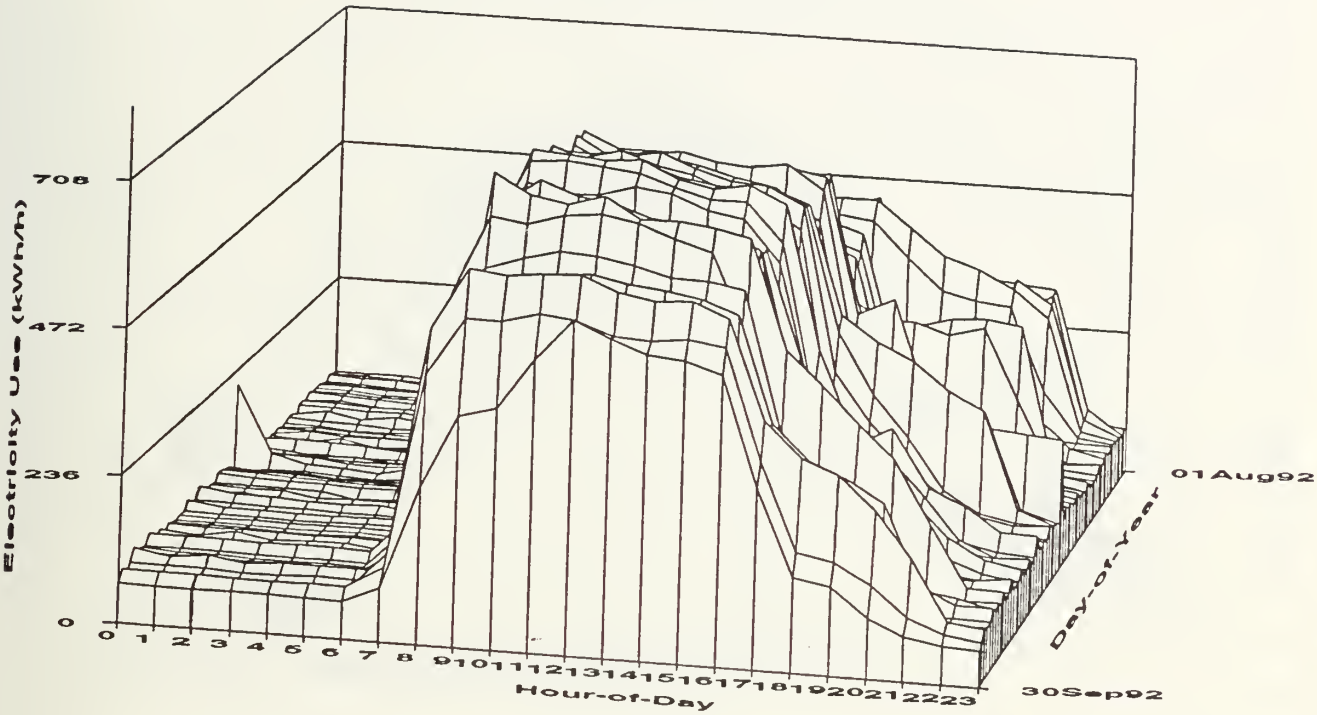
Whole–Building Electric



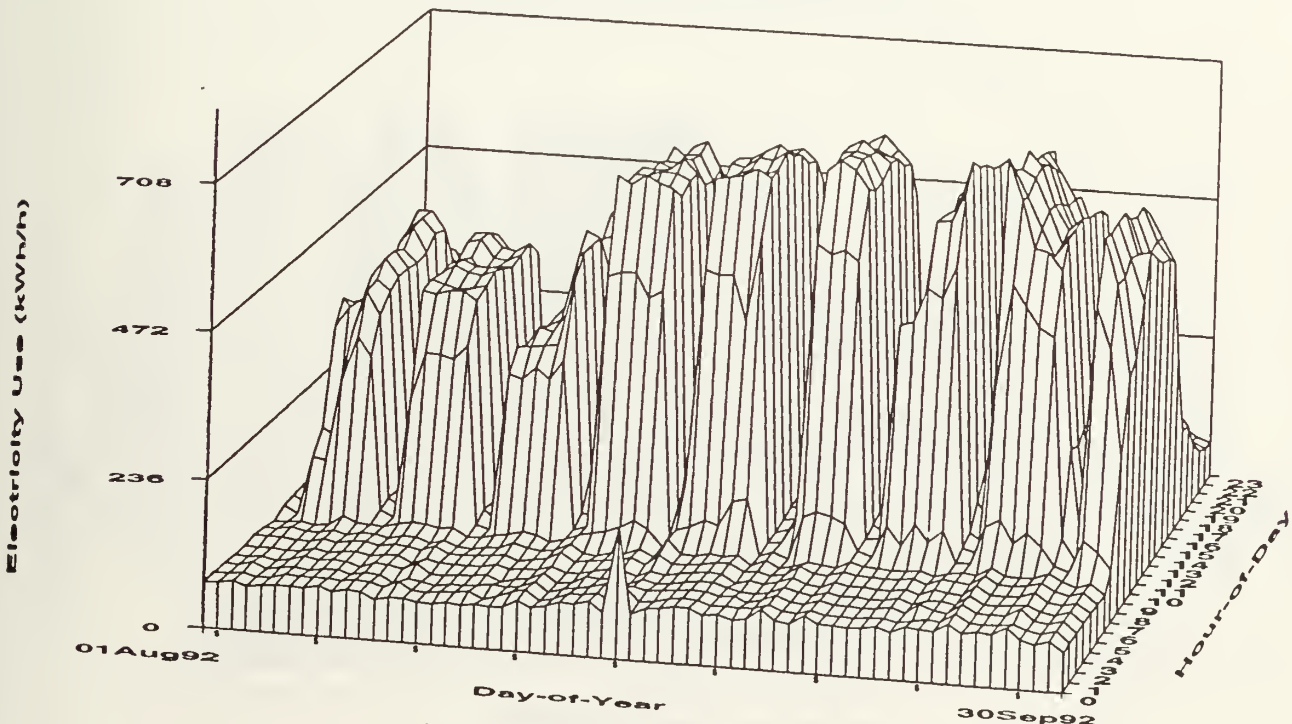
Sundays are marked with an "S"

Stroman High School - Victoria ISD - September 1991

Whole-Building Electric



Whole-Building Electric



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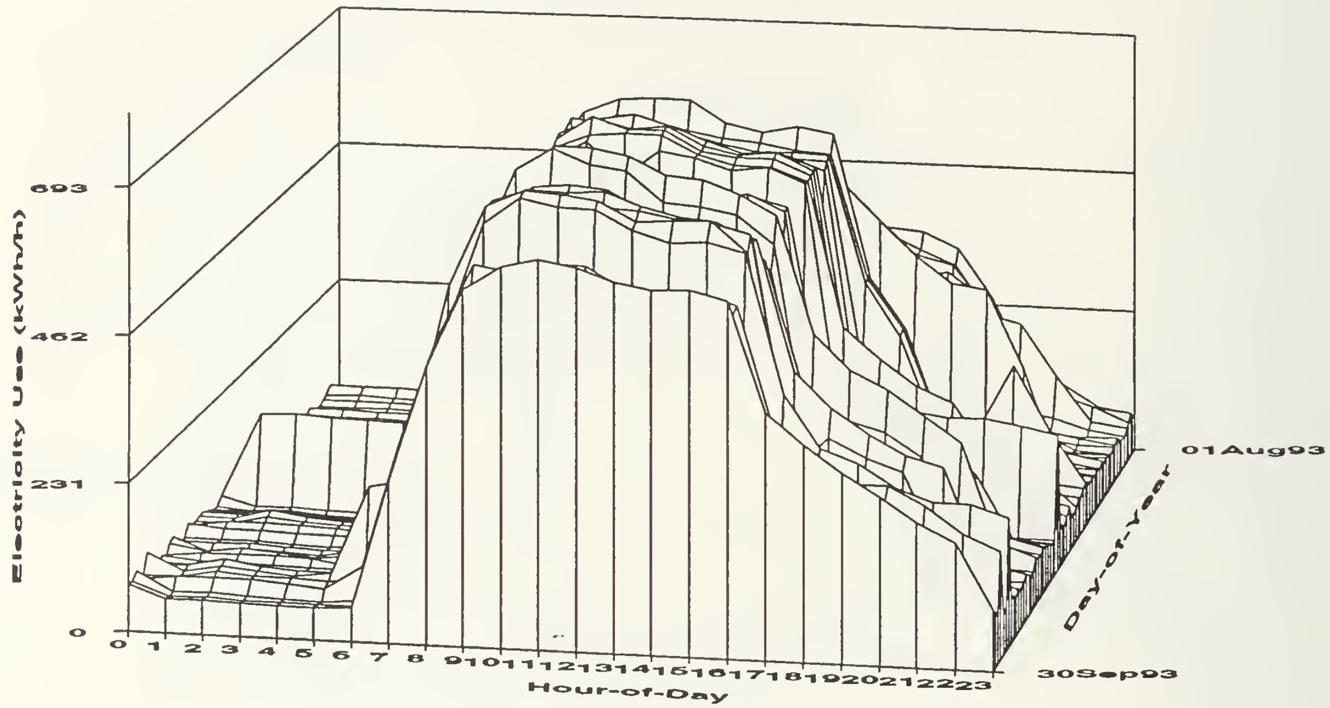
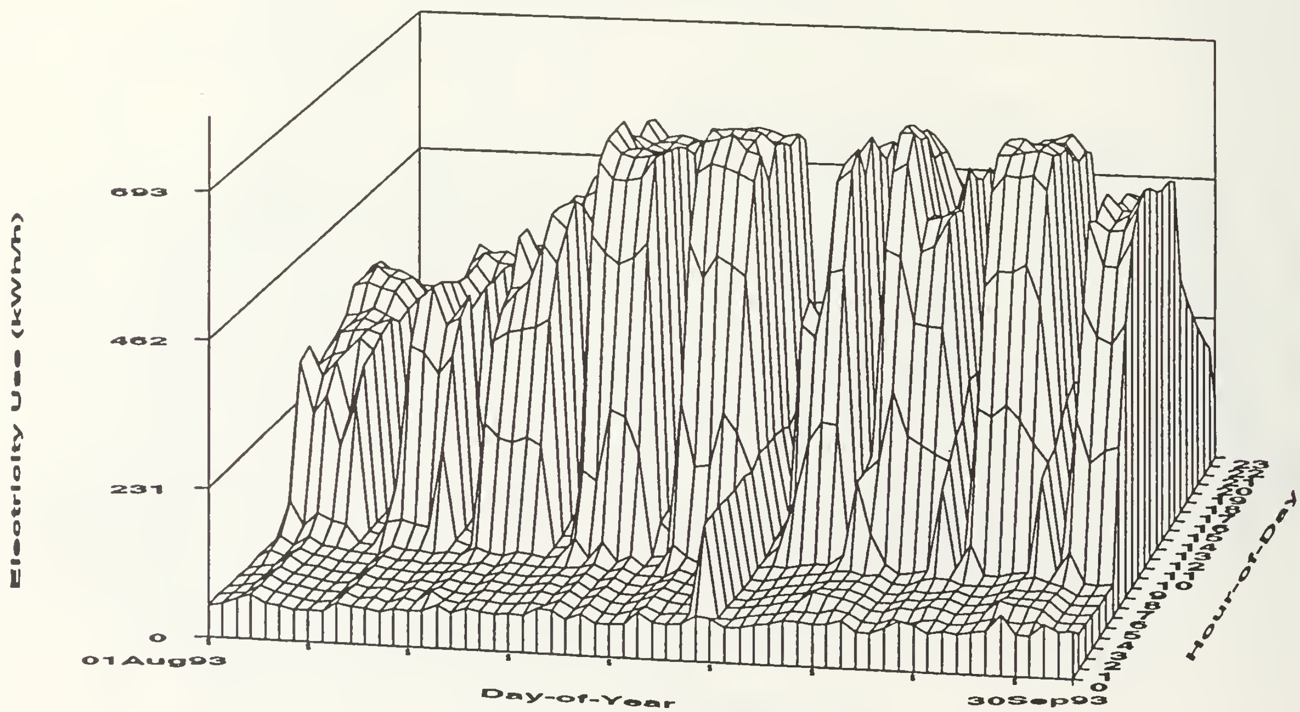
Whole–Building Electric



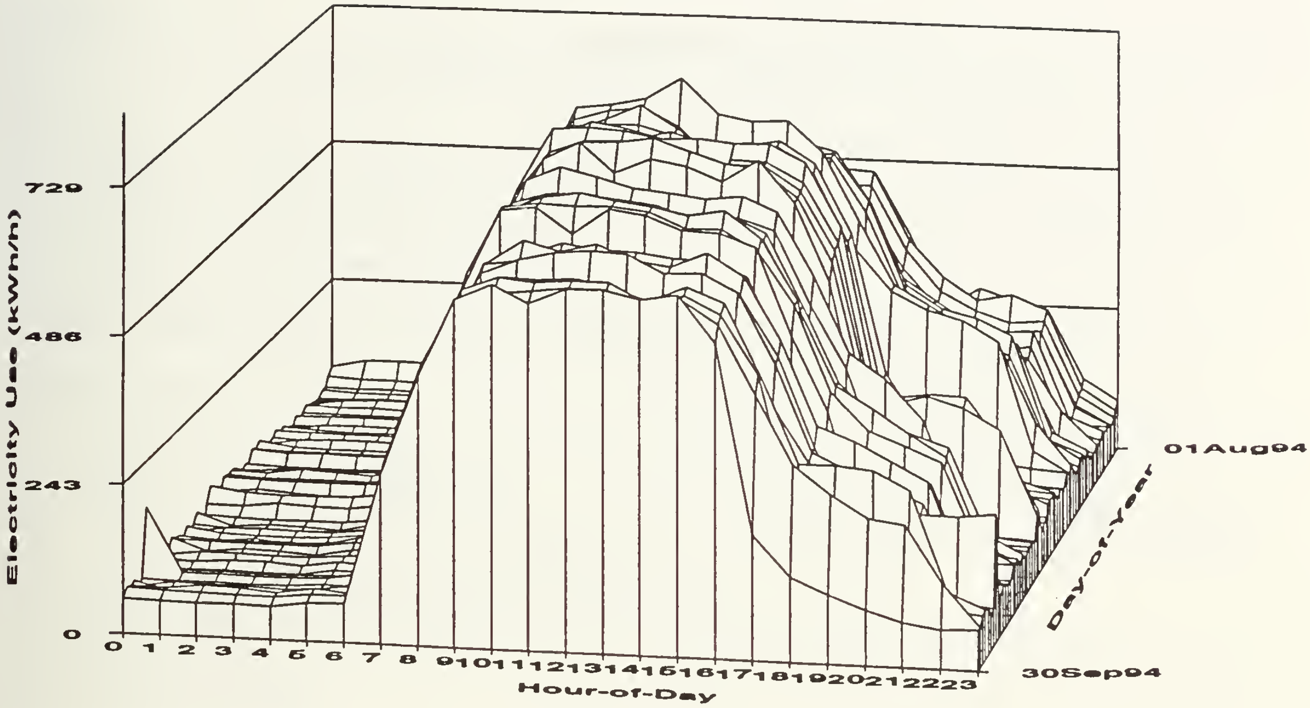
Whole–Building Electric



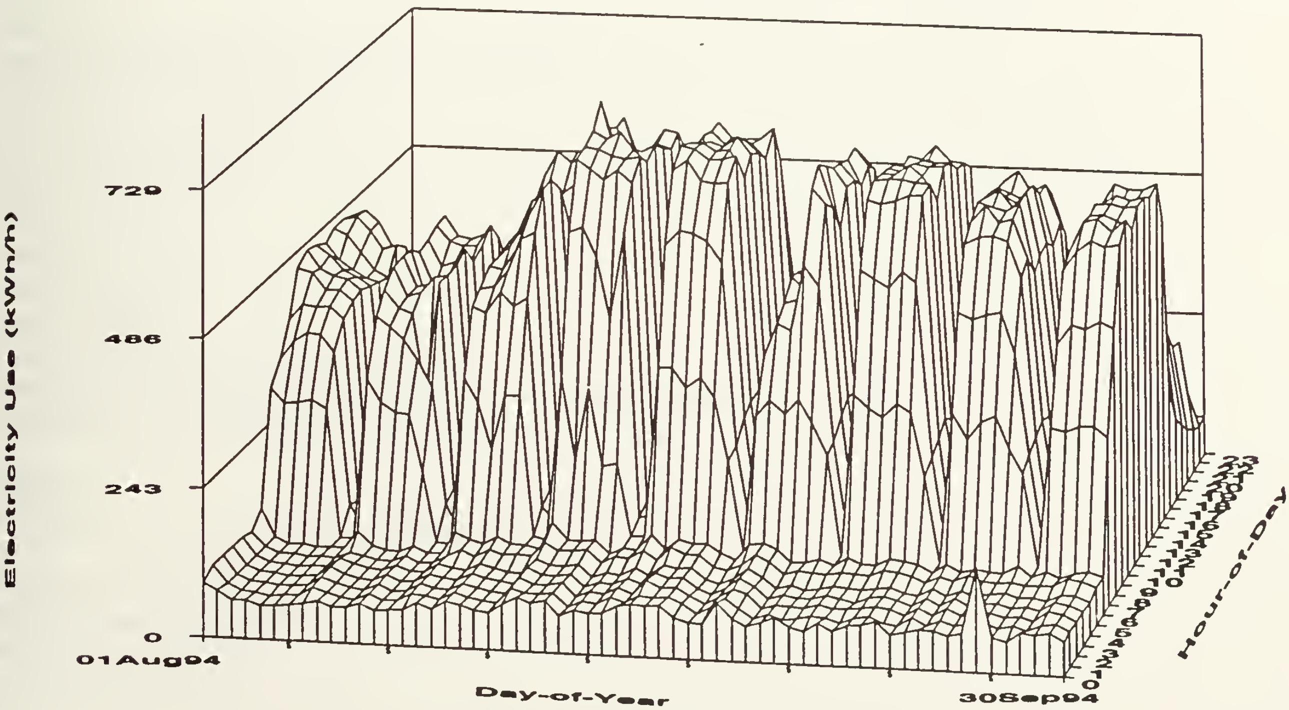
Sundays are marked with an "S"

Stroman High School - Victoria ISD - September 1993

Whole-Building Electric



Whole-Building Electric



Sundays are marked with an "S"

Stroman High School - Victoria ISD - September 1994

TAB A-6

Data Summary Notebook Information

VICTORIA INDEPENDENT SCHOOL DISTRICT

Stroman High School

Building Envelope:

- 210,500 sq.ft.
- Unit A: four storied, administrative offices on ground floor, classrooms on 2nd and 4th floors, 17,500 sq ft/floor.
- Unit B: 2 storied, auditorium, choir room, band room, and drafting classroom, 12,000 sq ft/floor.
- Unit C: single story, cafeteria and kitchen, 9,000 sq ft.
- Unit D and E: One contiguous building, 2 storied, library, gymnasium, locker rooms, and main mechanical room, 25,000 sq ft (Unit D), 27,000 sq ft (Unit E).
- Unit F: 2 storied, science classrooms, 23,000 sq ft.
- Unit G: single storied, shops, 7,000 sq ft.
- 3 Athletic Buildings: girls' gym, field house, and athletic dome, 25,000 sq ft.

Building Schedule:

- 7 am to 4 pm (M-F)

Building HVAC and Other Equipment:

- Unit A: 4 AHUs (1 mutizone of 7.5hp and 3 single zone of 3hp each), 50 fan-coil units and 1-45.8 ton chiller
- Unit B: 1 single zone AHU of 3hp and a rooftop DX unit
- Unit C: 2 single zone units of 0.75 hp each and 6 fan-coil units
- Unit D and E: 3 AHUs, 1 single zone of 5hp 2 H&V units of 2 hp each. and 2 fan-coil units
- Unit F: 18 fan-coil units
- Unit G: 2 rooftop DX units
- 18 exhaust fans (1/4 hp each)

HVAC Schedule:

- HVAC equipment is turned on manually at 7:00a.m. and turned off at 8:00p.m., on weekdays.

Auxillary Equipment:

- 3 single zone AHUs. @ of 3 hp each, 1 of 0.75hp.
- 1 - 50 hp chilled water pump.
- 1 - 20 hp hot water pump.
- 1 - 30 hp cooling tower.
- 1 - 2 hp boiler motor.
- 1 brine pump.
- 1 refrigerant pump.
- 1 reciprocating chiller of 3 hp.
- 2 gas fired boilers.
- 1 rooftop unit serving the First Aid room.
- 1 centrifugal chiller @ 460 tons (replaced 414 ton absorption chiller in Aug 91).
- 3 hot water heaters (500,000 Btu/hr each).

Lighting:

- mostly fluorescent (40 W). Total lighting load 260 kW.

Proposed Retrofits:

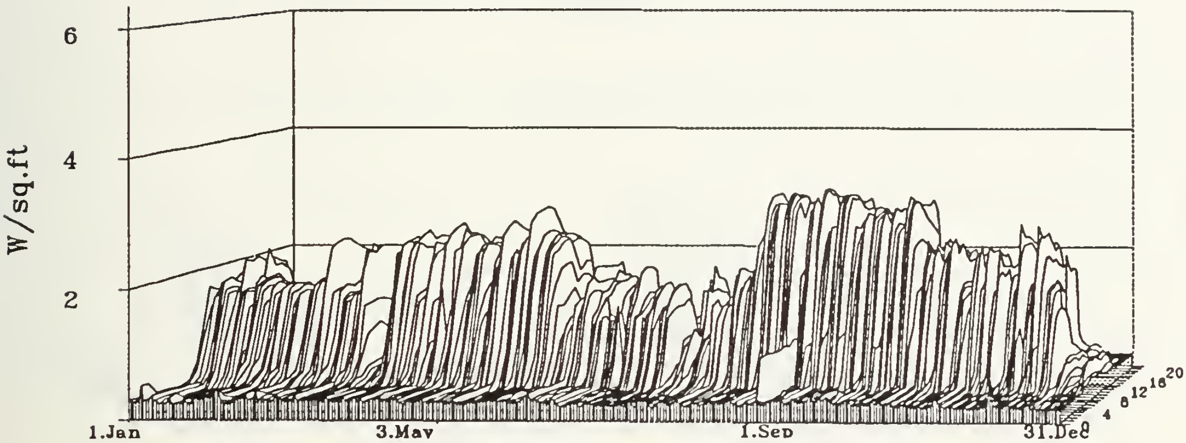
- Energy Management System.
- replace absorption chiller.
- rewire wiring in hallways.

Date of Retrofits:

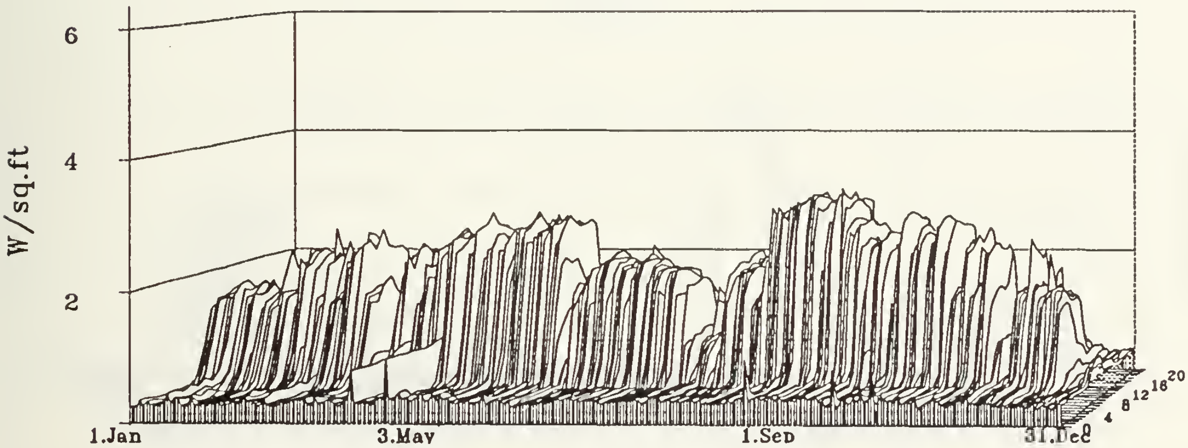
- replacement of absorption chiller was completed in August 1991. Work on the other two retrofits was completed in January 1992.

Stroman High School (SHS)
W.B. Electric as W/sq.ft.

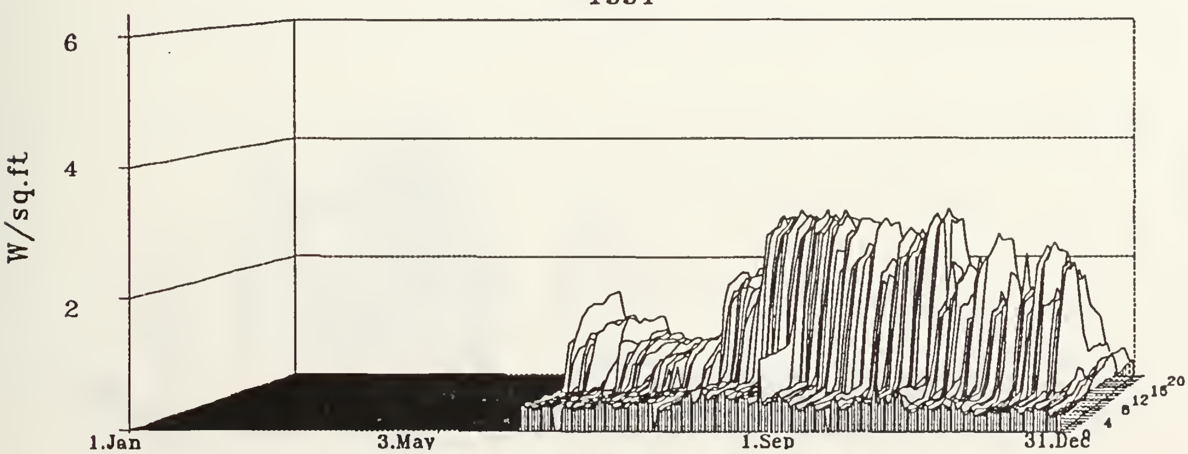
1993



1992

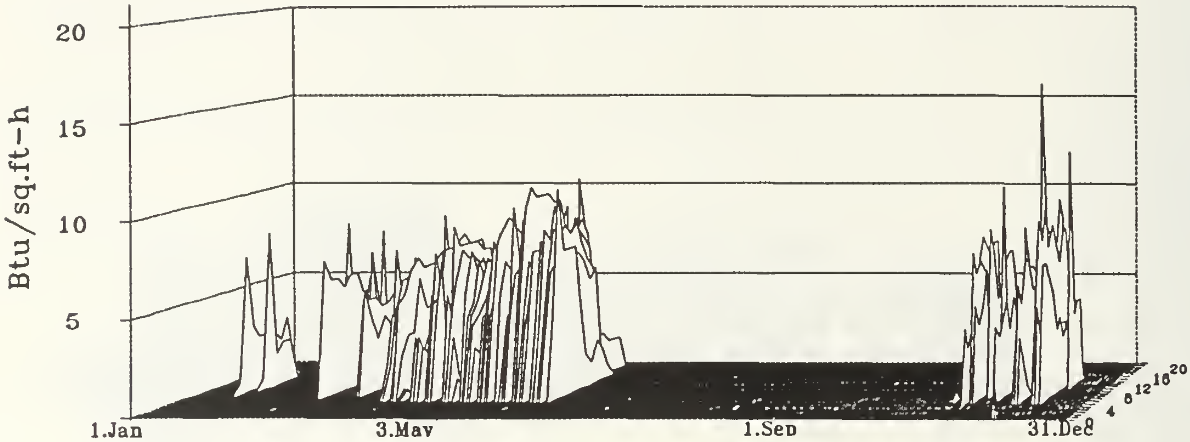


1991



Stroman High School (SHS)
W.B. CHW as Btu/sq.ft.-h

1993



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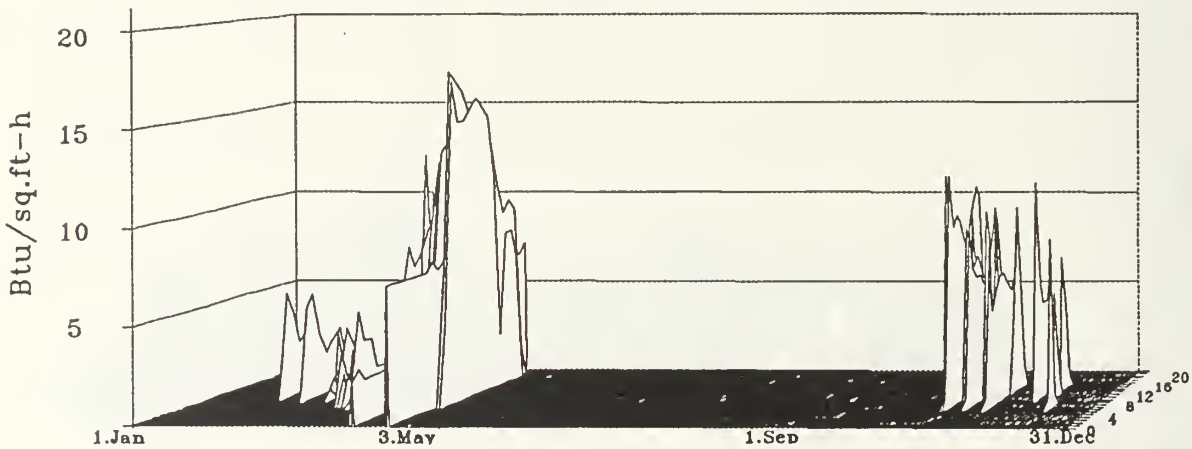

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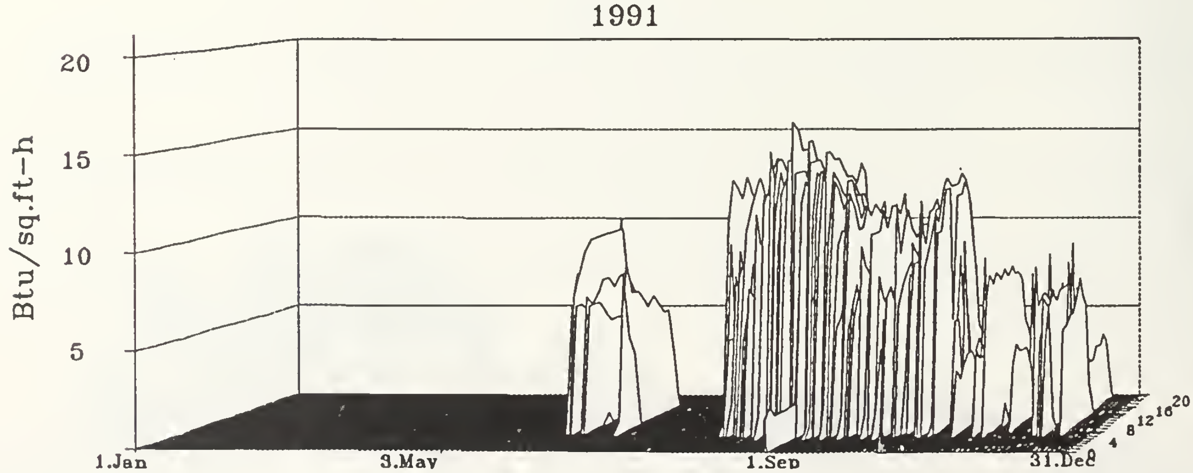
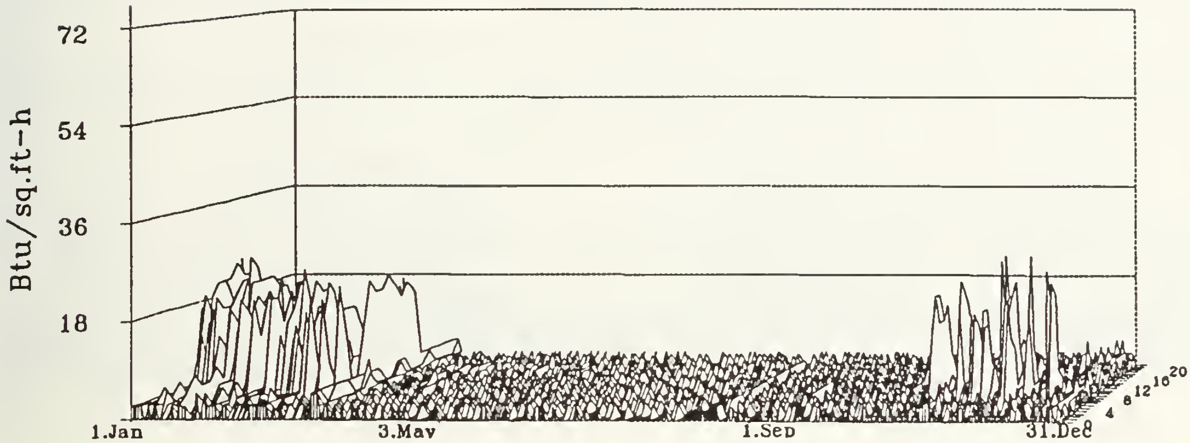


Stroman High School (SHS)
W.B. HW as Btu/sq.ft.-h

1993



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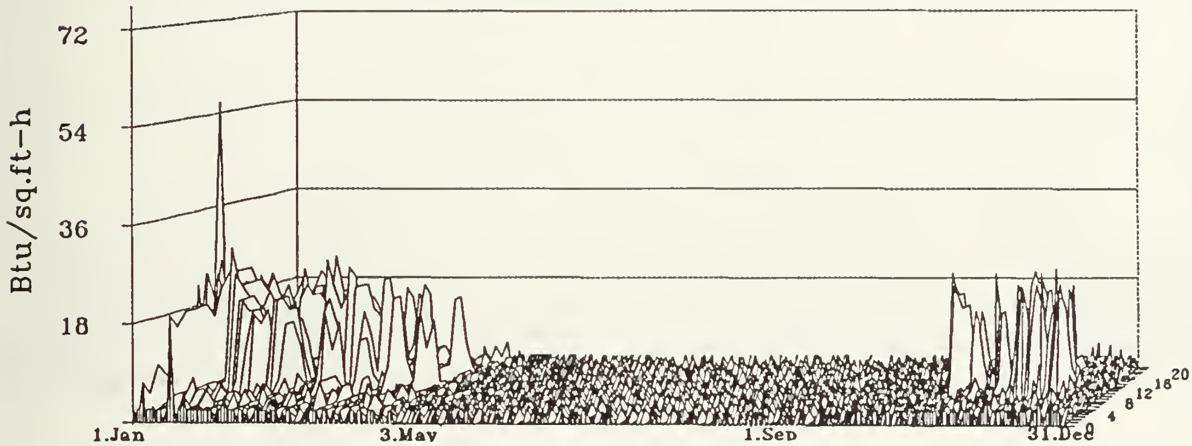
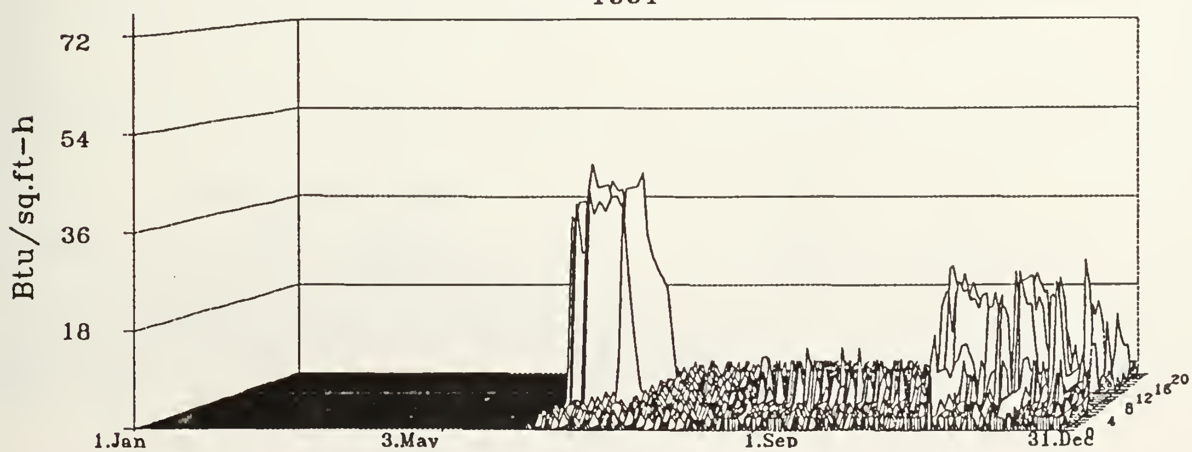
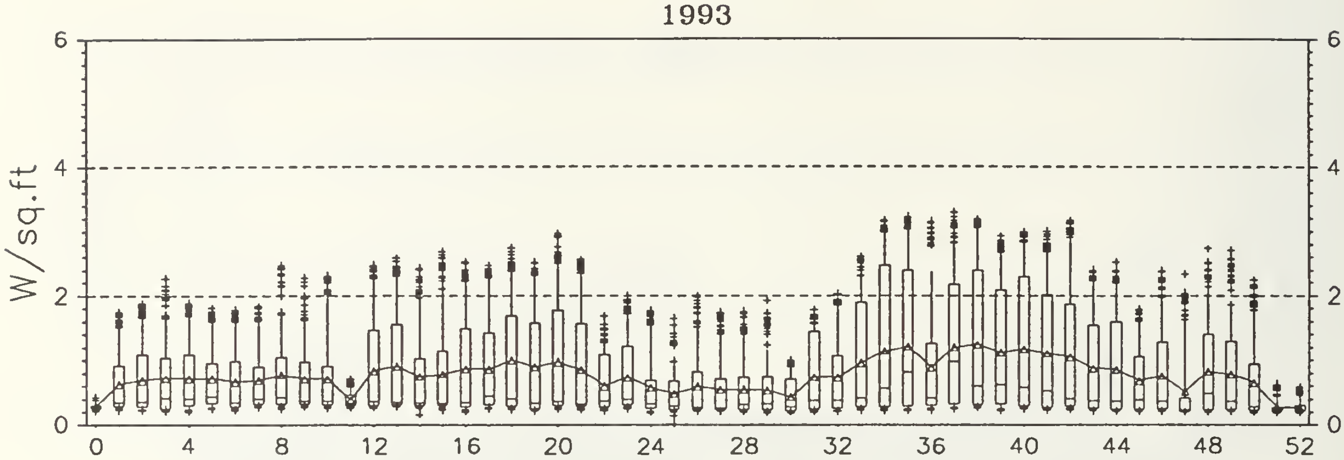
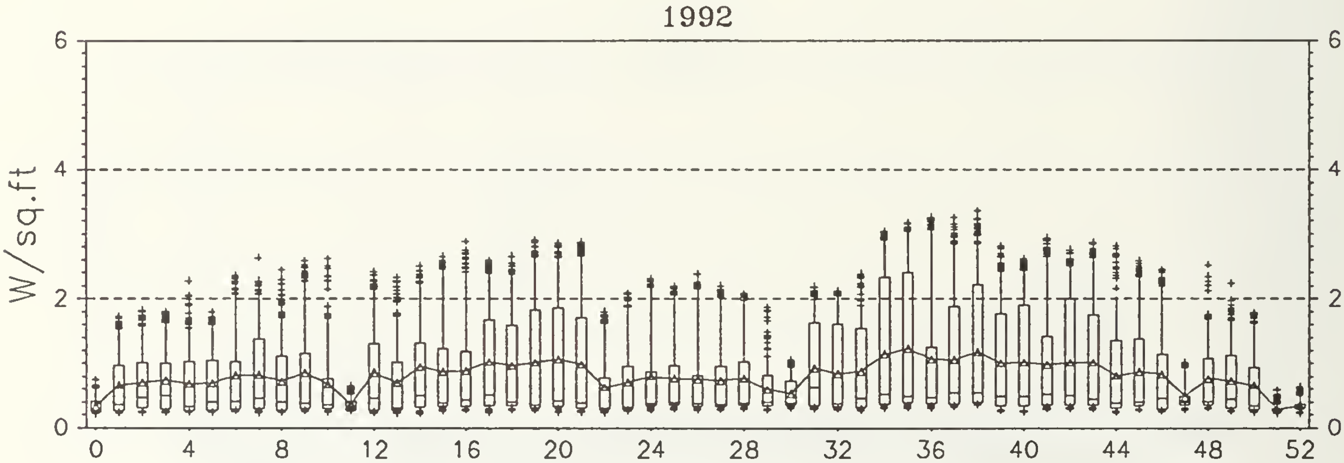


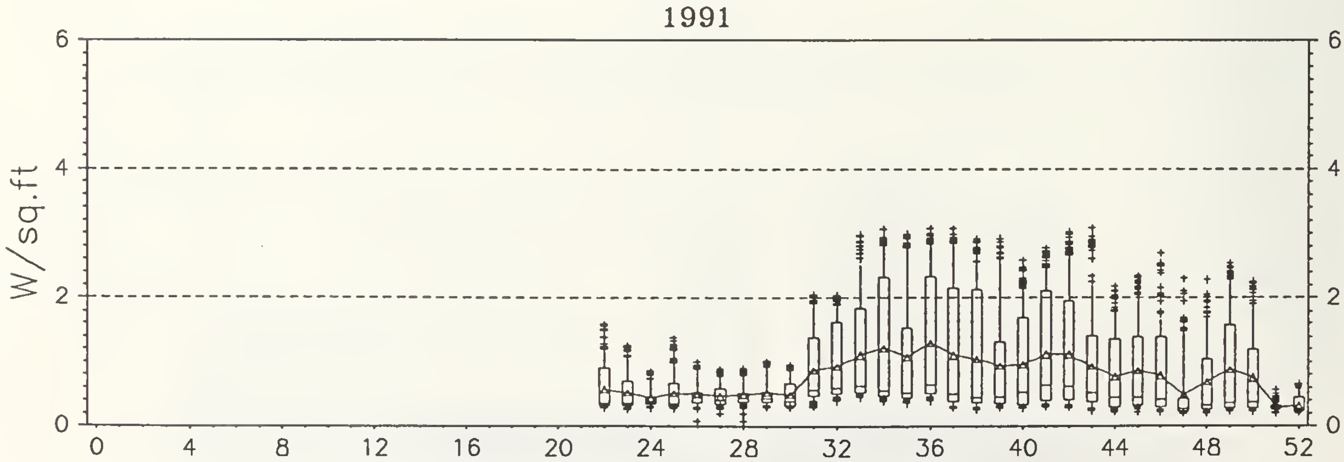
1991



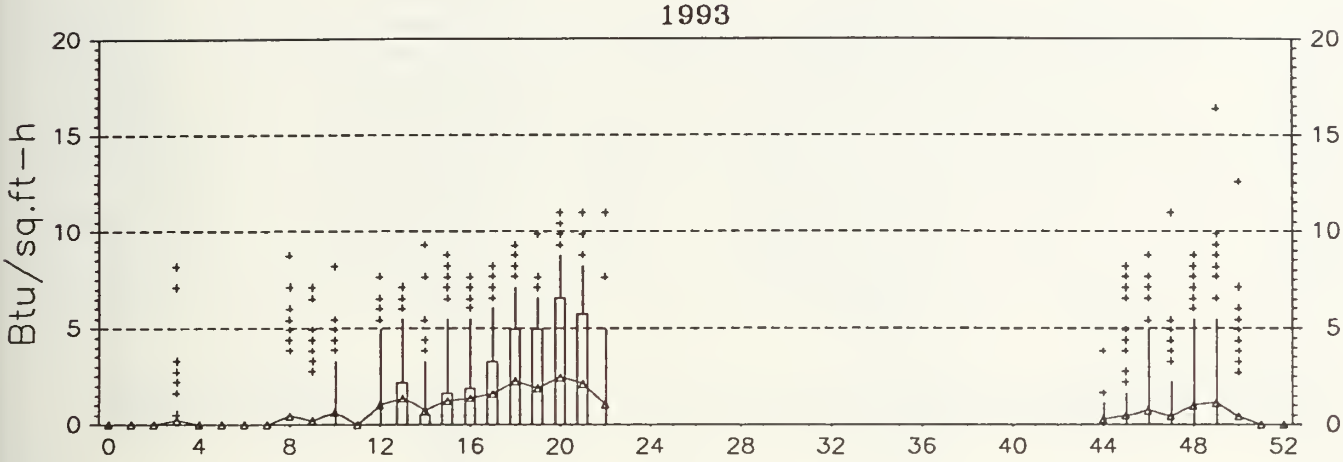
Stroman High School (SHS)
W.B. Electric as W/sq.ft.

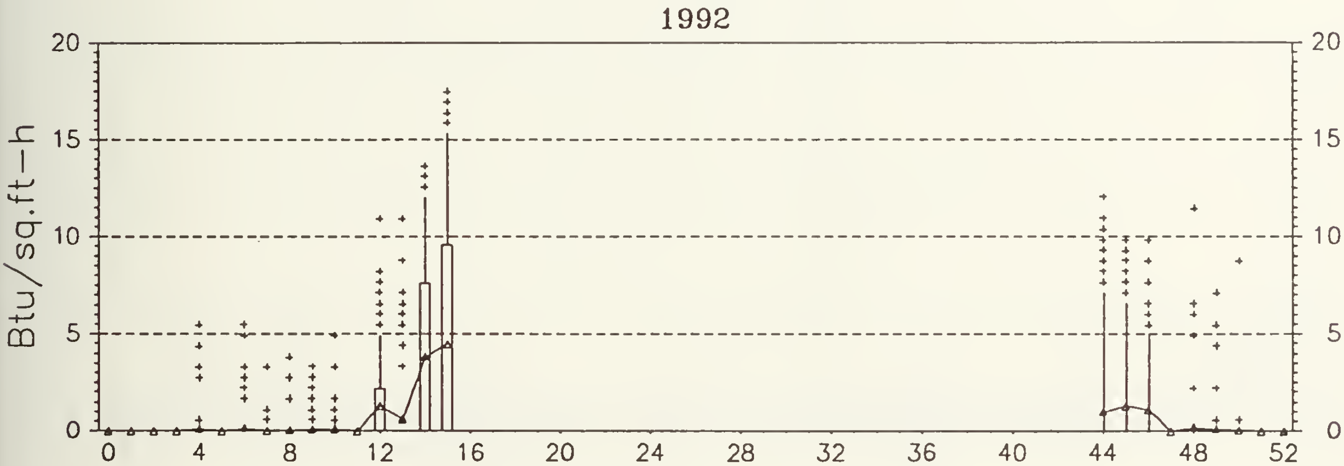


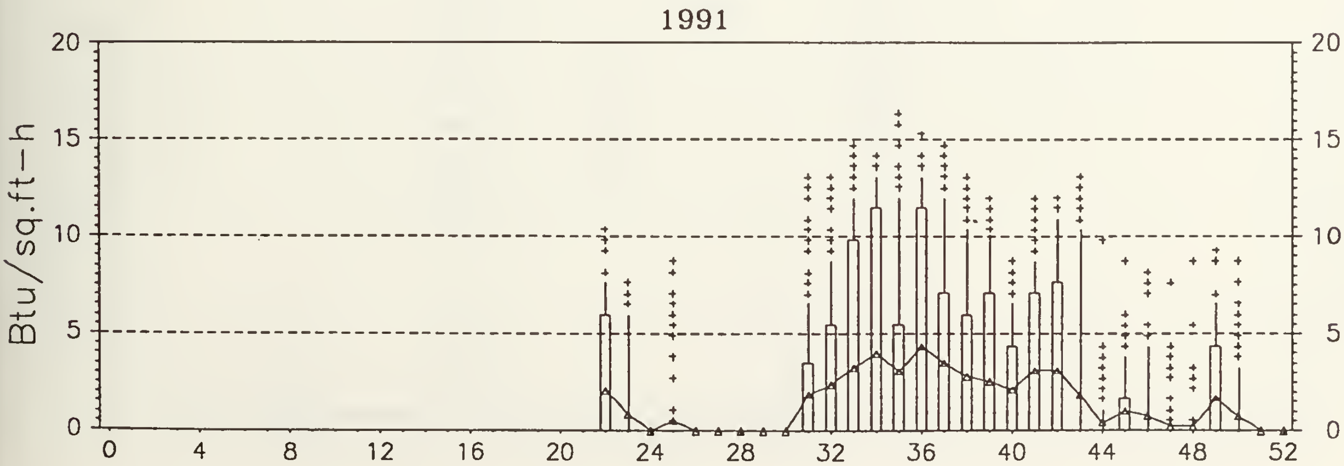




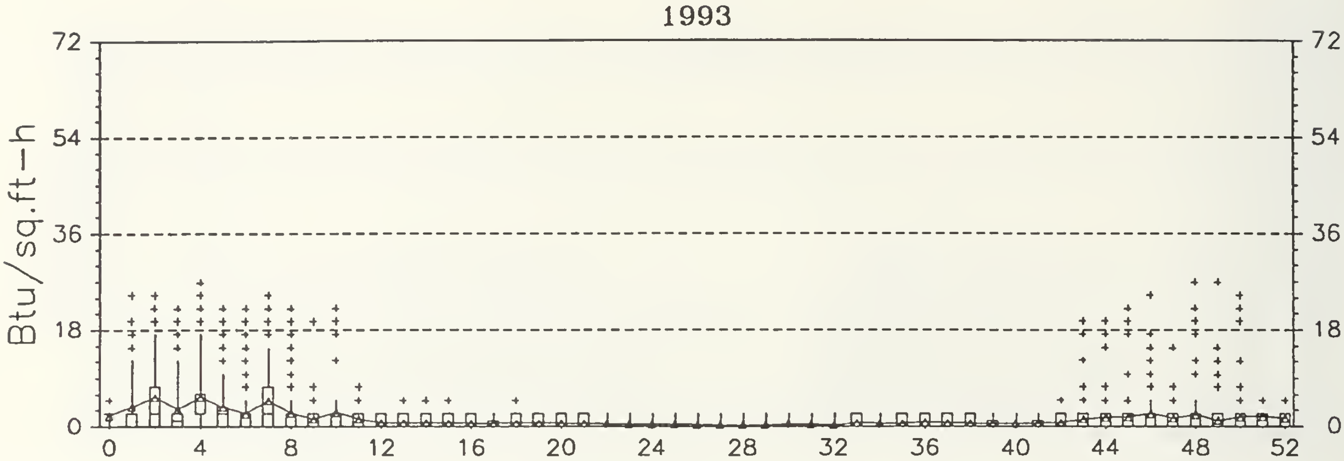
Stroman High School (SHS)
W.B. CHW as Btu/sq.ft.-h

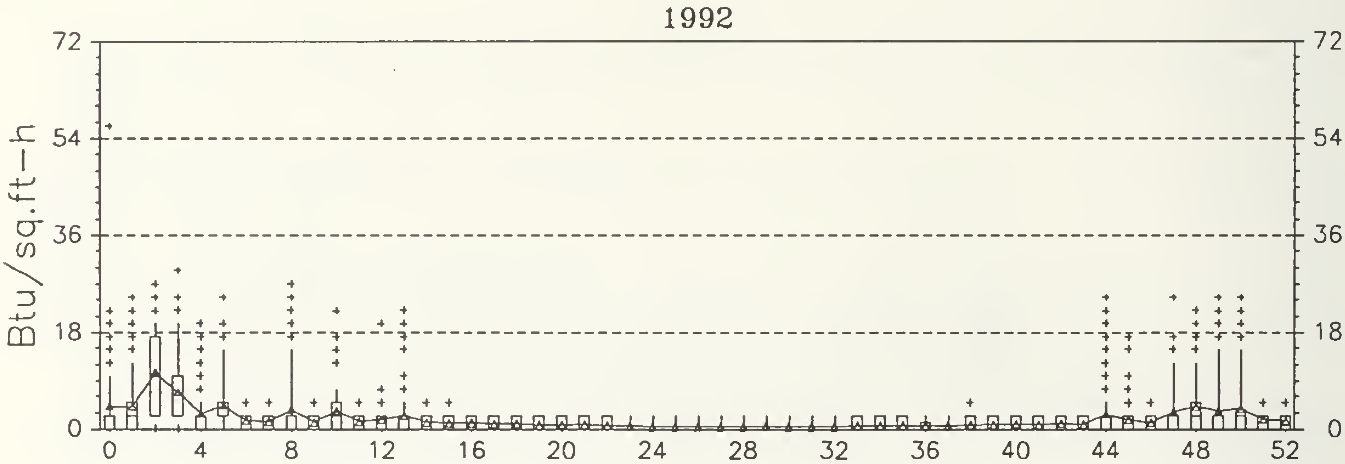


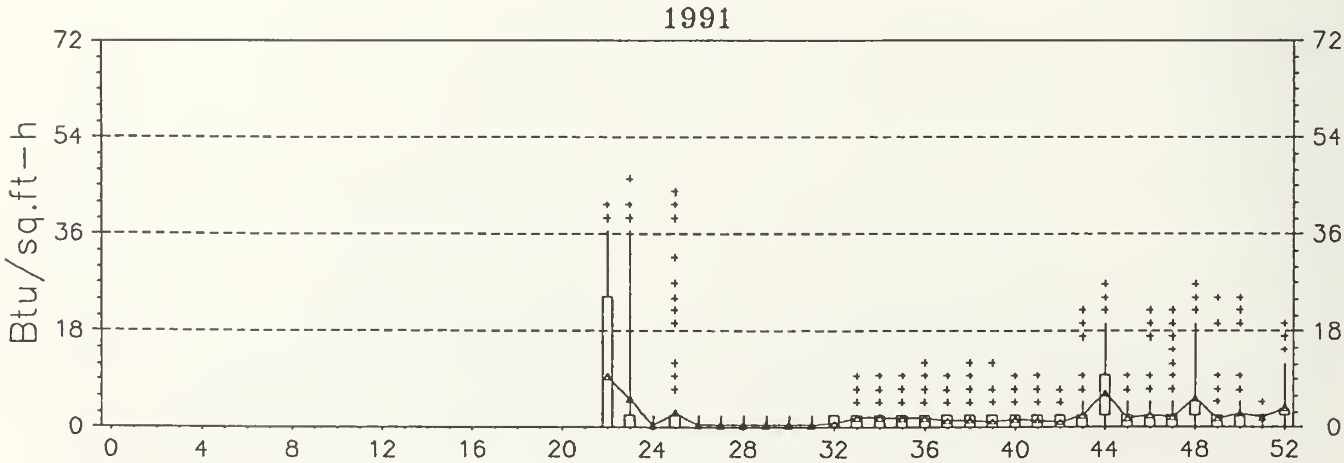




Stroman High School (SHS)
W.B. HW as Btu/sq.ft.-h



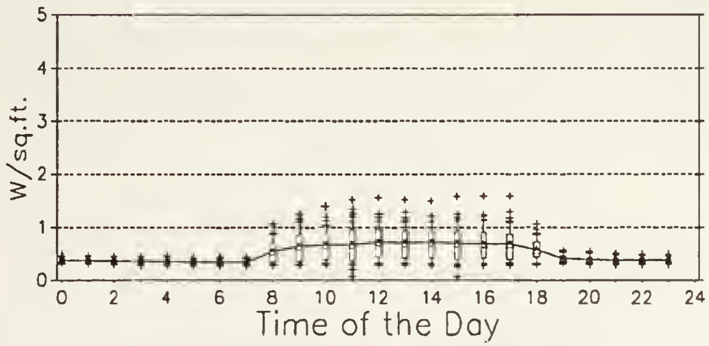




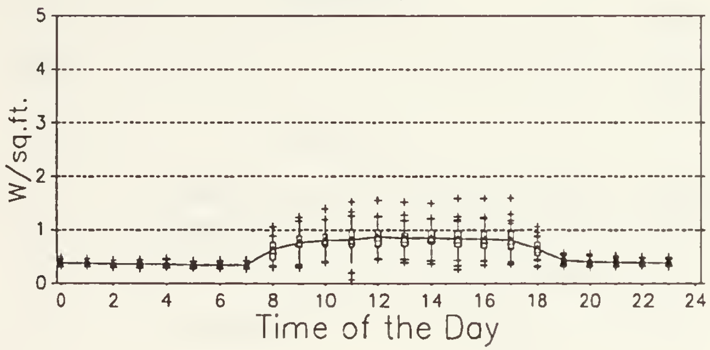
Stroman High School (SHS)
W.B. Electric as W/sq.ft.

Pre-Retrofit (06/04/1991 - 08/01/1991)

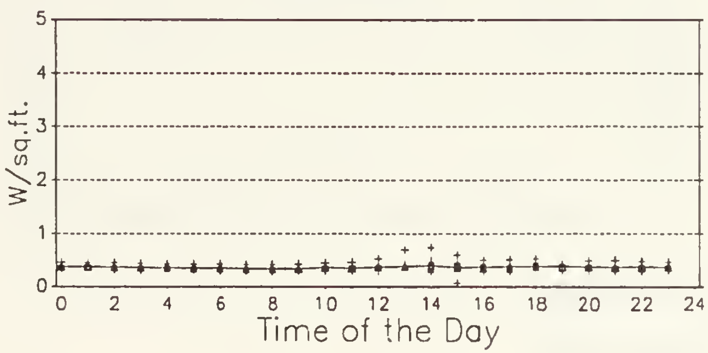
Everyday



Weekdays

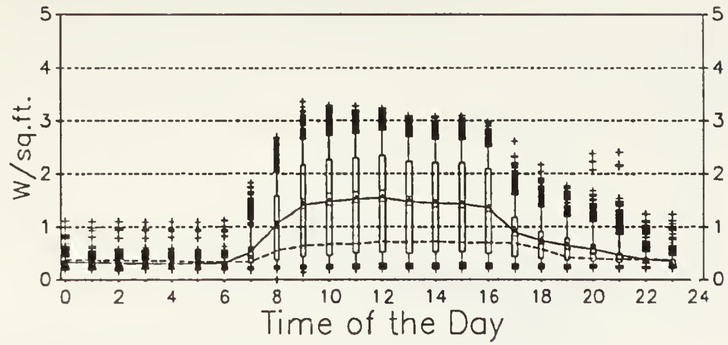


Weekends

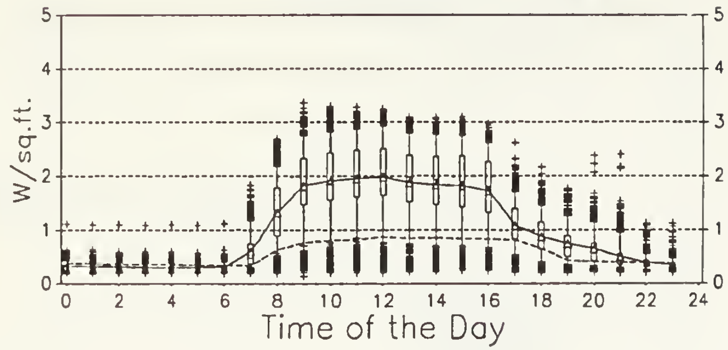


Post-Retrofit (08/15/1991 - 12/31/1993)

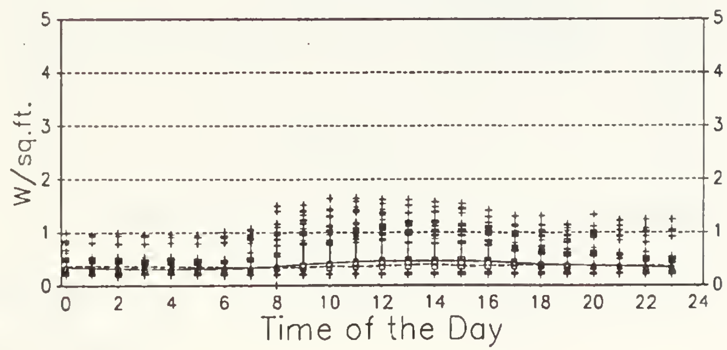
Everyday



Weekdays



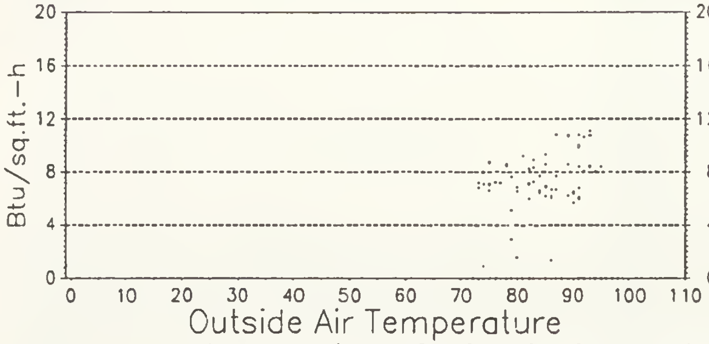
Weekends



Stroman High School (SHS)
W.B. CHW as Btu/sq.ft.-h

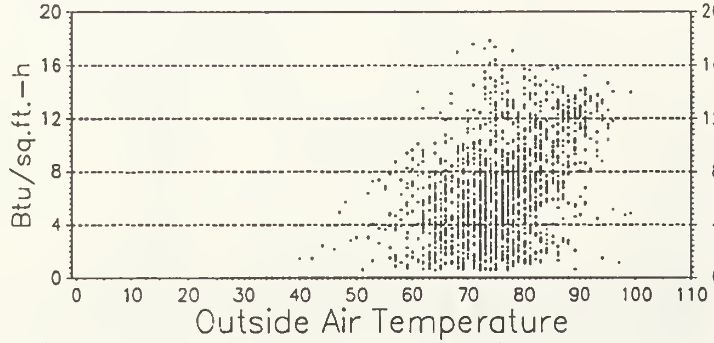
Pre-Retrofit (06/04/1991 - 08/01/1991)

Everyday



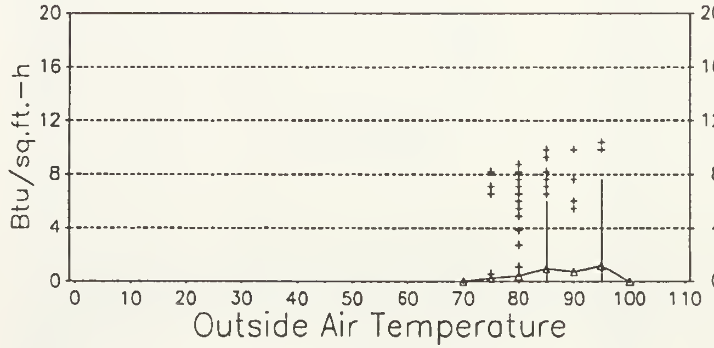
Post-Retrofit (08/15/1991 - 12/31/1993)

Everyday

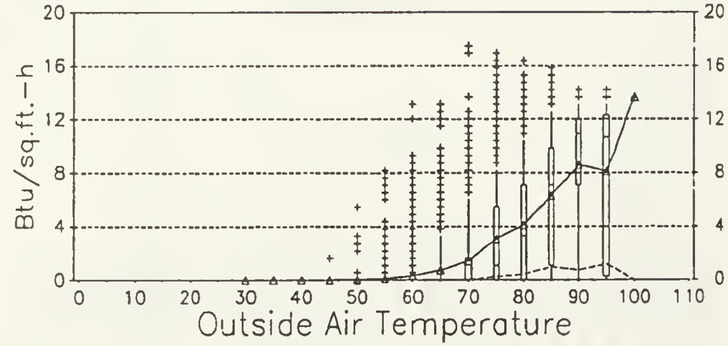


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

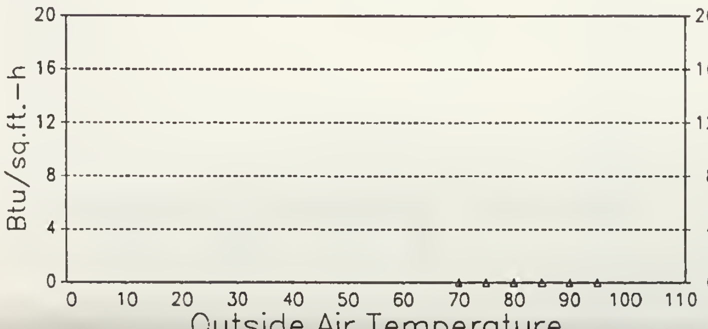
Weekdays



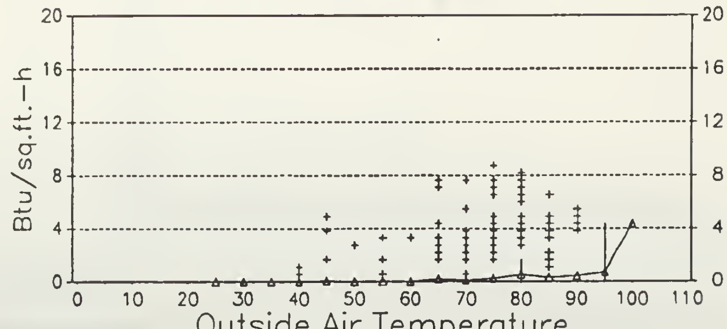
Weekdays



Weekends



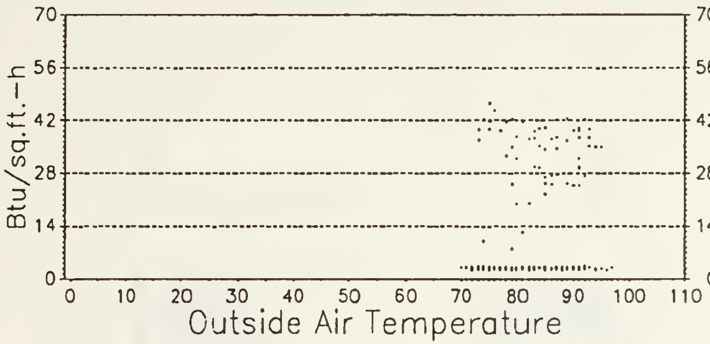
Weekends



Stroman High School (SHS)
W.B. HW as Btu/sq.ft.-h

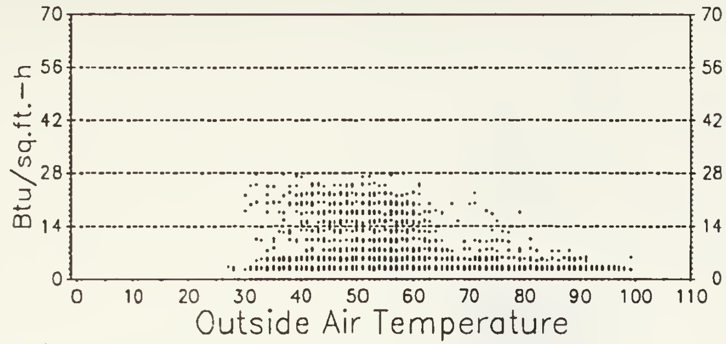
Pre-Retrofit (06/04/1991 - 08/01/1991)

Everyday



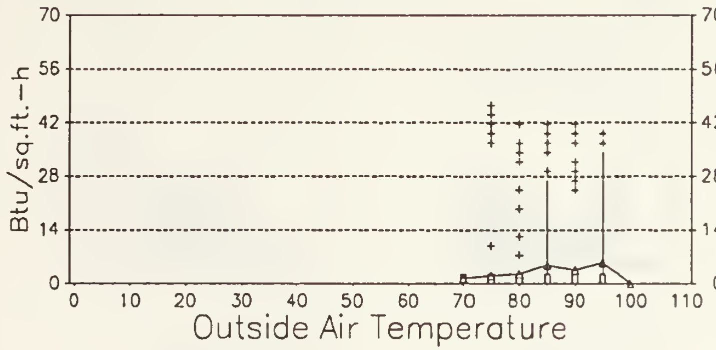
Post-Retrofit (08/15/1991 - 12/31/1993)

Everyday

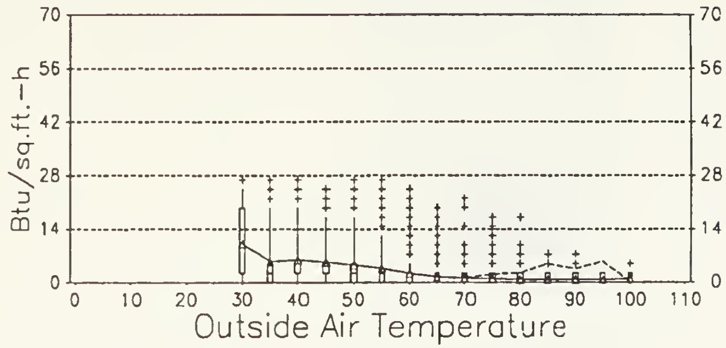


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

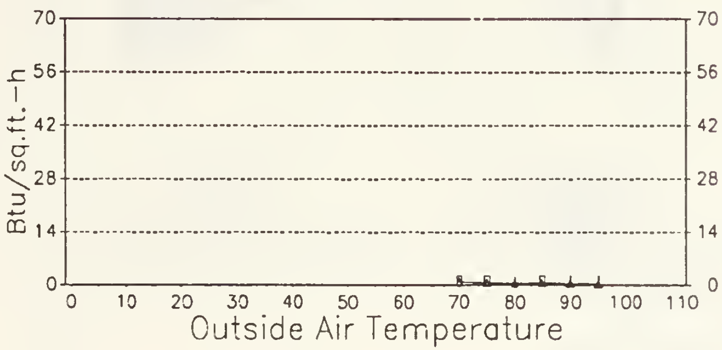
Weekdays



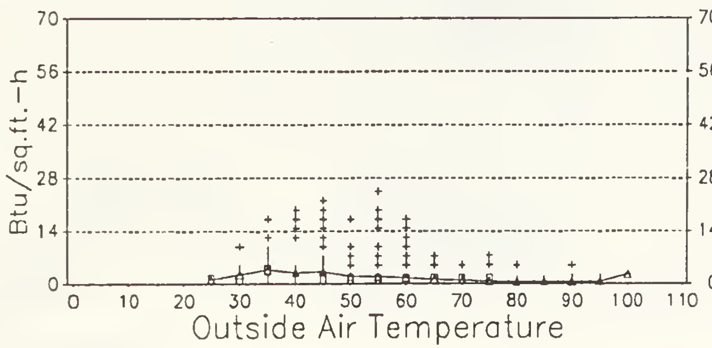
Weekdays



Weekends

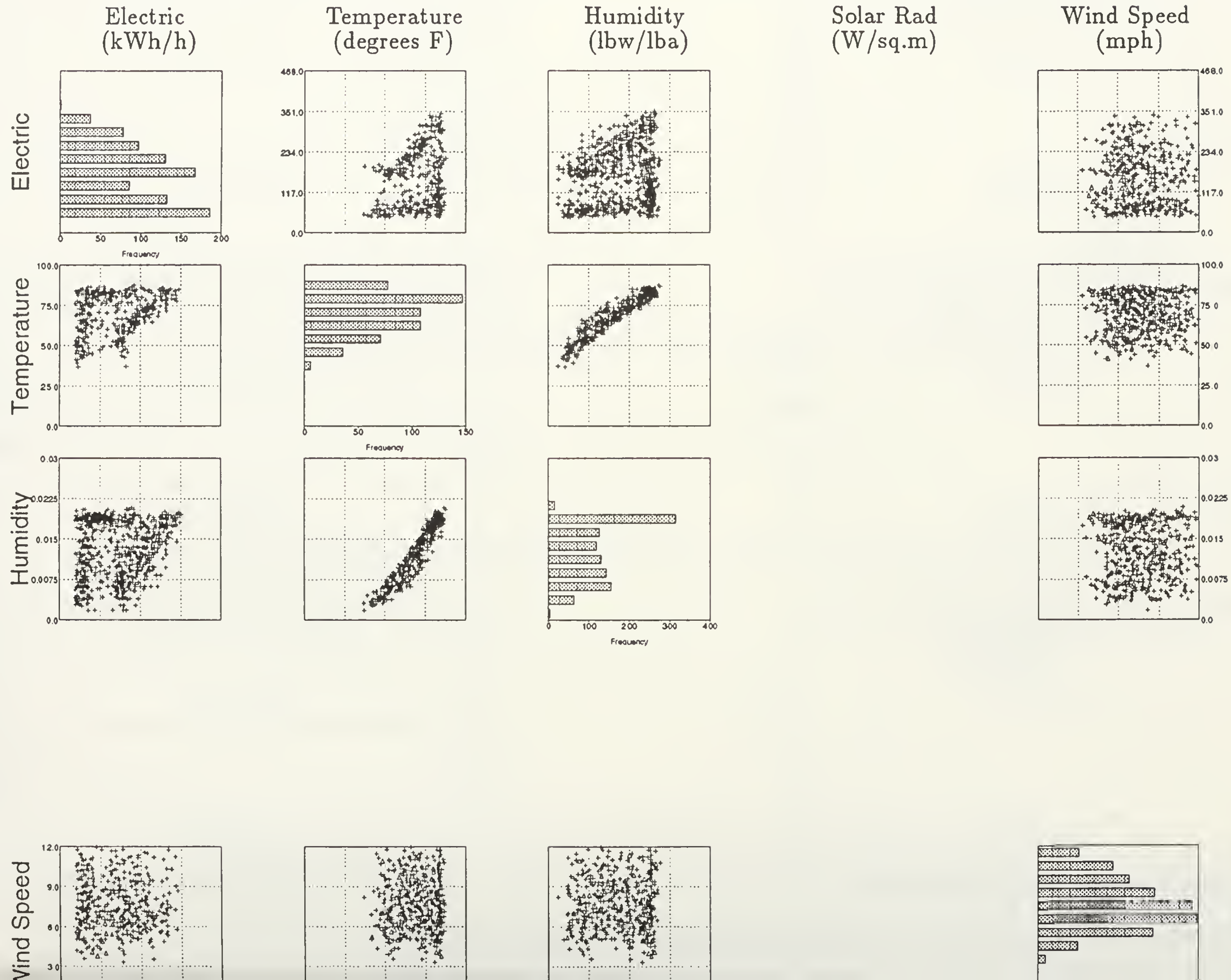


Weekends



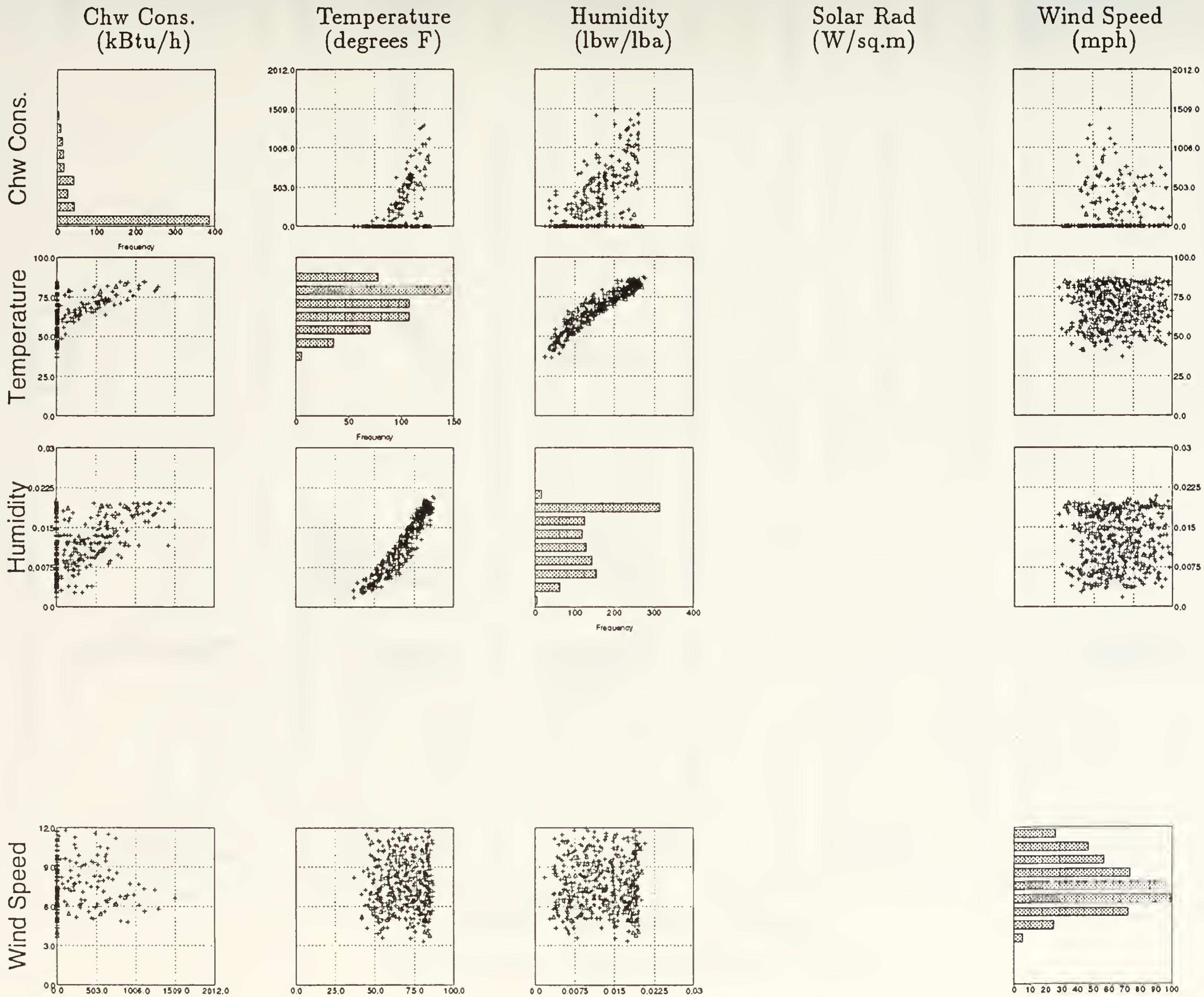
Stroman High School (SHS)
Daily Average Values

Pre-Retrofit (△) 06/04/1991 - 08/01/1991 Post-Retrofit (+) 08/15/1991 - 12/31/1993



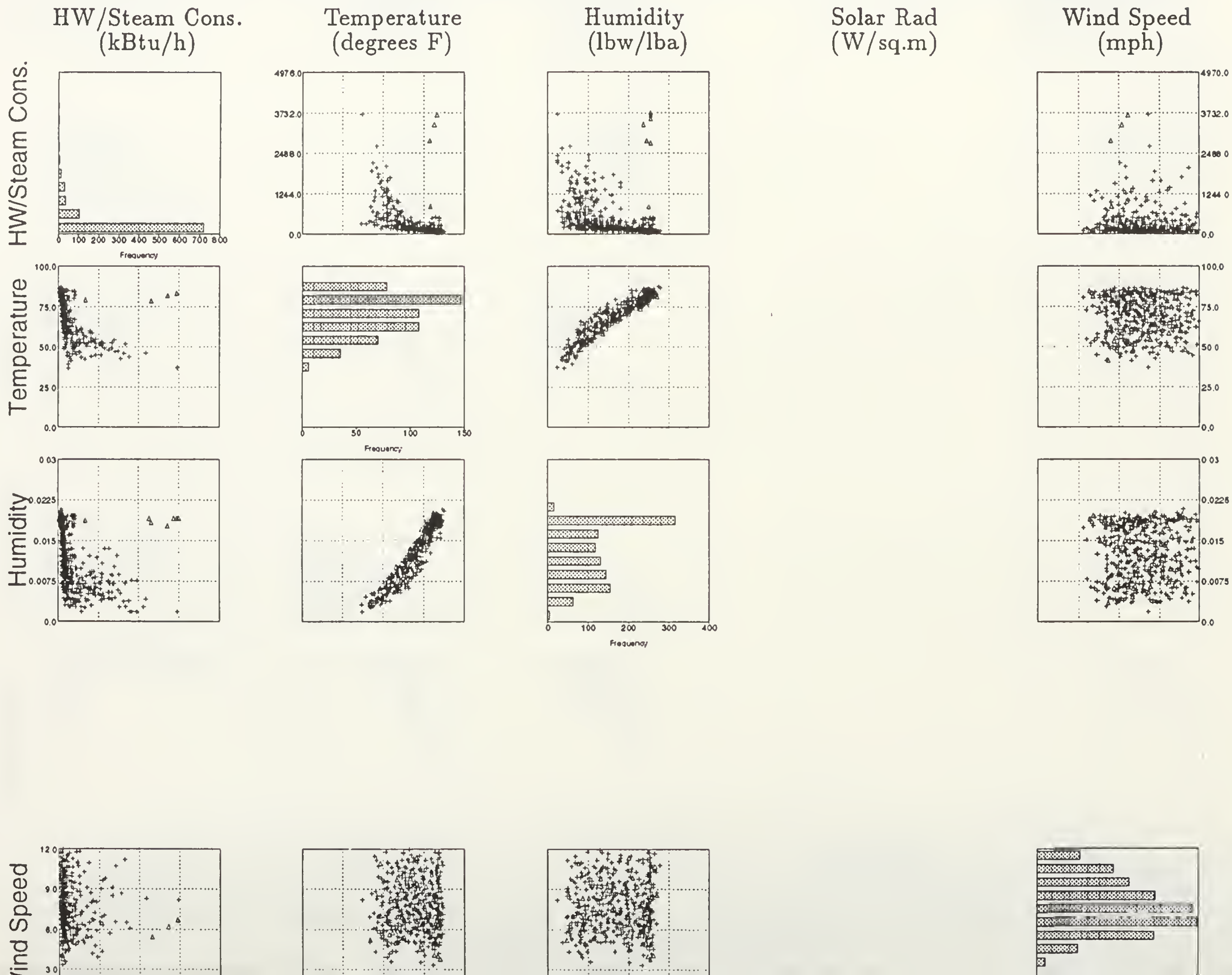
Stroman High School (SHS)
Daily Average Values

Pre-Retrofit (Δ) 06/04/1991 - 08/01/1991 Post-Retrofit (+) 08/15/1991 - 12/31/1993



Stroman High School (SHS)
Daily Average Values

Pre-Retrofit (△) 06/04/1991 - 08/01/1991 Post-Retrofit (+) 08/15/1991 - 12/31/1993



B. VICTORIA HIGH SCHOOL

B.1 Site Description[1]

Victoria High School is located in Victoria, Texas. It consists of ten buildings with a total floor area of 257,014 square feet. The two largest buildings are the Main Building and the Academic Wing. Both of these buildings are two-story, brick, slab on grade, with flat roofs. Both buildings are served by hydronic fan-coil units. The chiller serving the Main Building is a 192 ton centrifugal chiller, with 25 horsepower chilled water and condenser pumps, and a 15 horsepower cooling tower fan. The chiller serving the Academic Wing is a 182 ton chiller with a 20 horsepower chilled water pump, a 15 horsepower condenser water pump, and a 20 horsepower cooling tower fan. The eight remaining buildings are all single story, served by rooftop units with direct expansion cooling and gas heating. These buildings include a field house/dressing room, two shop buildings, a gymnasium, special education building, learning resource center, home economics building, and a multipurpose building with kitchen, cafeteria, band hall, and choir rooms.

Air distribution is primarily through single duct air handling systems, providing cooling temperatures of approximately 75 °F, and heating temperatures within the range of 70 to 72 °F. Heating and air handling systems are turned off completely during the night and are controlled from a central location through a Carrier EMCS.

The school is operated from the middle of August through the middle of May, with approximately 2,135 students and 228 faculty and staff. The maximum school occupancy is from about 8:00 a.m. until 4:00 p.m.; however, the building is occupied for much longer periods, including weekends and summers. Stroman and Victoria High School alternate as the primary location for summer school. Victoria was the site during the summer of 1992. School district calendars for the reporting period of June 5, 1991, through June 4, 1994, are included in Tab B-1.

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[1]Adapted from: Landman, D.S., 1995. "Preliminary Study of Advanced Diagnostic Prescreening Methods," Energy Systems Laboratory, Mechanical Engineering Department, Texas A&M University, College Station, TX.

Electricity is purchased from Central Power and Light Company. Natural gas is purchased from ENTEX Gas Company.

B.2 EMCS Retrofit

The energy audit for Victoria High School determined that the HVAC operation was controlled manually, which resulted in excessive operating hours in each of the schools in the school district. Timeclock controls were installed many years ago, but were not suited for the needs of the school. See Tab B-2 for the full text technical analysis of the facility, which was provided in the audit.

The proposed EMCS retrofit called for the installation of a direct digital control-based EMCS, which would control all HVAC equipment, measure exterior and interior space temperatures, and measure humidity in one or two critical locations within the school. The EMCS would have no override timers that custodial staffs could activate. Operating hours of all HVAC units would be determined by the maintenance staff, and controlled by that staff from its central headquarters via modem.

The EMCS system was installed and activated on January 31, 1992. It controls the HVAC equipment and some lights, and measures the temperature and humidity at select locations. Although there are override capabilities, they are not used.

B.3 Analysis

B.3.1 Snapshot of consumption for September 1991 through December 1993

Figures B-1 and B-2 represent monthly average consumption and peak consumption versus min-max average (or peak) monthly temperature.[2] Min-max average monthly temperature is calculated by averaging the maximum and minimum temperature each day to obtain min-max average daily temperature. The daily temperatures are then averaged over all days in each month to obtain min-max average monthly temperature.

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[2] Landman, D.S., 1995. "Preliminary Study of Advanced Diagnostic Prescreening Methods," Energy Systems Laboratory, Mechanical Engineering Department, Texas A&M University, College Station, TX.

The data points reflecting high temperature and low consumption are indicative of non-semester consumption. If those data points are ignored, there is a general increase of consumption with temperature, indicating a temperature dependence of consumption. Additionally, the post-retrofit data points are generally lower than the pre-retrofit data points. When compared to similar plots for other Texas schools in the LoanSTAR program, this site is a low energy use school. However, it does have higher energy use than Stroman High School. The reader is referred to the referenced report for a more detailed discussion of these plots.

Figure B-1: ***Monthly Average Consumption:*** **Consumption, in W/sf, versus min-max average monthly temperature, in °F, for September 1991 through December 1993 (Victoria High School)**

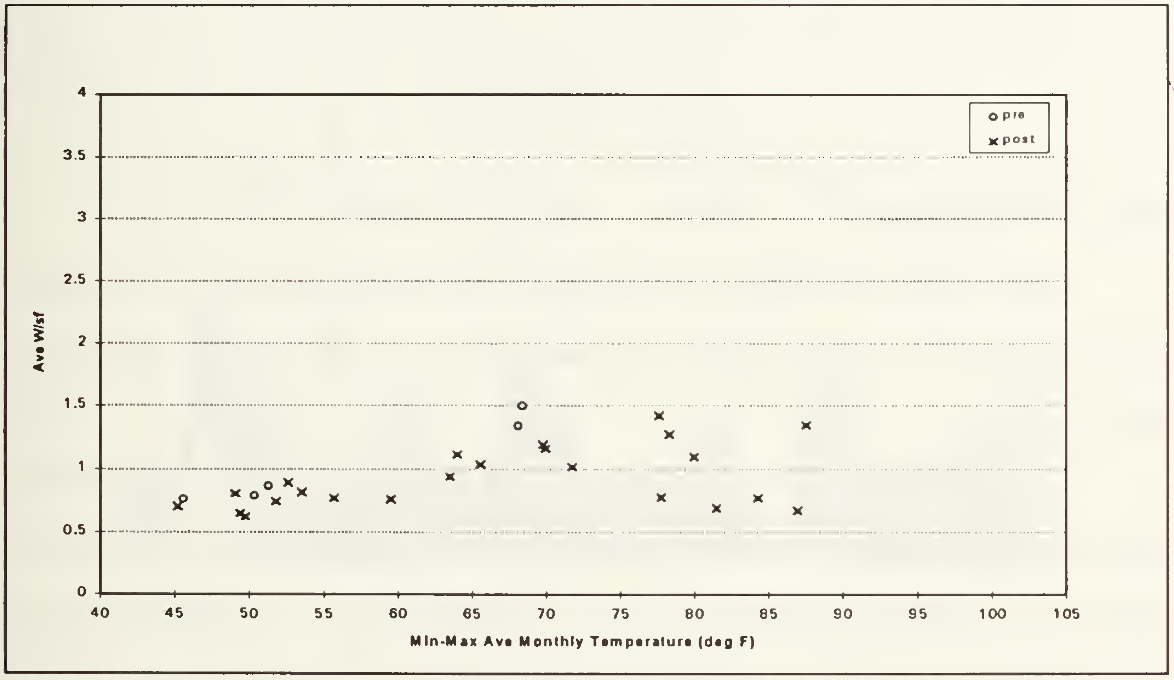
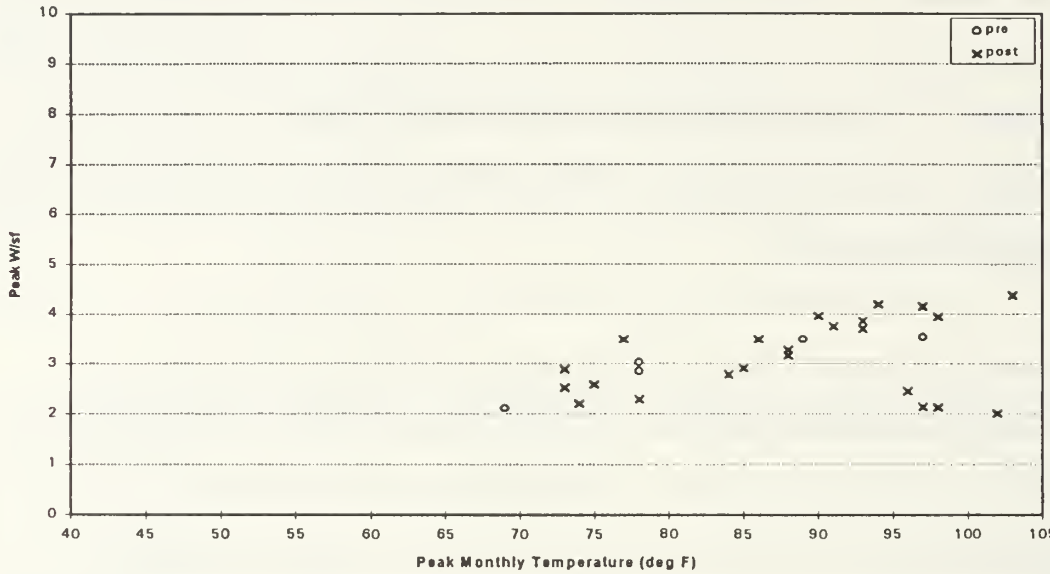


Figure B-2: ***Monthly Peak Consumption:*** **Consumption, in W/sf, versus peak monthly temperature, in °F, for September 1991 through December 1993 (Victoria High School)**



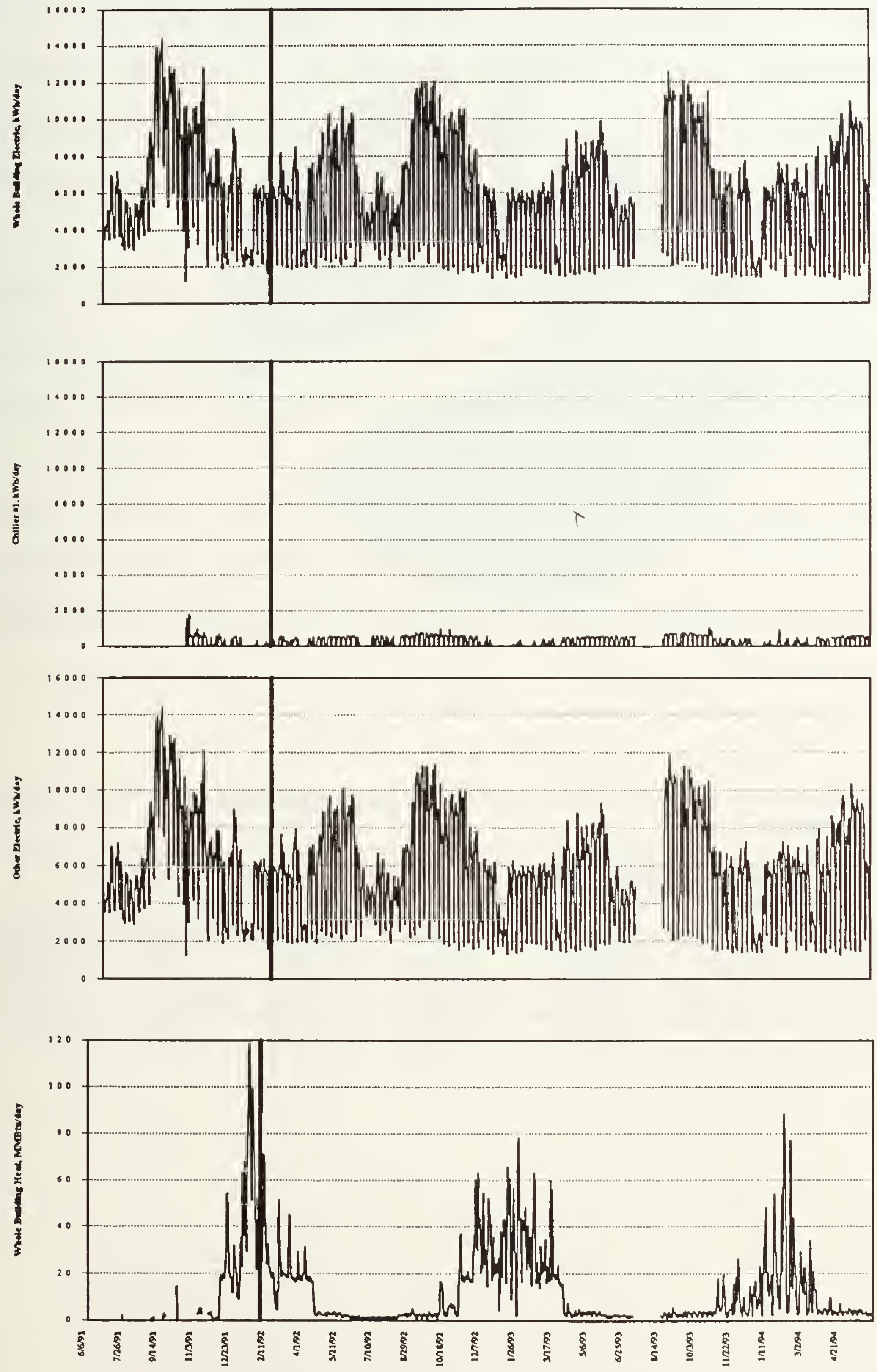
B.3.2 Timeline plots

Plots of energy consumption for the reporting period are shown in Figure B-3. The EMCS retrofit date of January 31, 1992, is shown by a vertical, bold line. Monitoring diagrams are provided in Tab B-3.

In looking at the whole building electric plot, there is no apparent decrease in consumption at any point along the timeline. There was an a chiller installed as a concurrent retrofit at this site. This resulted in the appearance of chiller consumption in September 1991. Any possible decrease in consumption due to the EMCS may have been offset by the increase in consumption due to the new chiller. The appropriate plot to analyze the effects due only to the EMCS is the "other electric" plot, which is whole building electric minus the chiller. Here, a drop in consumption is evident between the pre-retrofit and post-retrofit periods

The plot of whole building heat shows seasonal heating between November and April of each year. There is also a decrease in consumption evident between the pre-retrofit and post-retrofit periods.

Figure B-3: *Energy Consumption time series* **for June 1991 to June 1994 (Victoria High School)**



B.3.3 Whole Building Electricity Consumption (Post Period)

Table B-1 shows energy consumption for the post period (February 1, 1992, through June 4, 1994). Whole building electricity consumption is broken down into two components: chiller #1 electricity consumption and other electricity consumption. It is further subdivided into semester period and non-semester periods. The post-retrofit period is used because there is significantly more data available in the post-retrofit period, and it represents current usage.

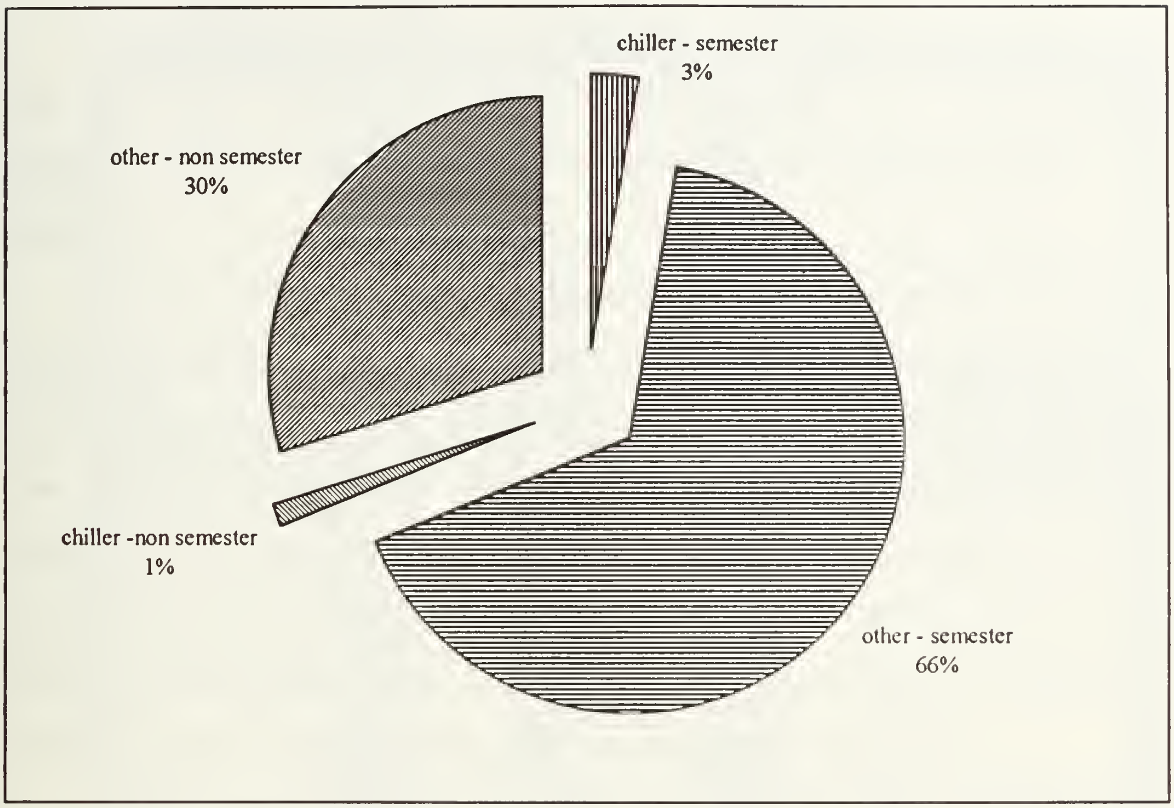
Figure B-4 graphically shows whole building electricity consumption for the post period. For the semester period, 66% of whole building electric energy use is attributable to other electric equipment, while 3% is due to electric chiller #1. For the non-semester period, other electric accounts for 30% of whole building electric energy, while chiller #1 accounts for 1%.

From both Table B-1 and Figure B-4, it is readily apparent that chiller #1 accounts for a small portion of the whole building electricity usage. Therefore, attention for reducing energy usage should be focused on the other electricity usage. In this case, other electricity consumption is primarily roof-top HVAC units and lighting.

Table B-1: ***Energy Consumption*** **for post period, February 1992 through June 1994 (Victoria High School)**

	SEMESTER		NON-SEMESTER		TOTAL	
	ENERGY	$	ENERGY	$	ENERGY	$
wbelec, kWh	3,343,246	$93,210	1,262,155	$35,189	4,605,400	$128,399
chlr #1, kWh	159,076	$4,435	60,298	$1,681	219,374	$6,116
other, kWh	3,184,170	$88,775	1,201,857	$33,508	4,386,027	$122,282
wbheat, MMBtu	7,847	$37,271	1,888	$8,966	9,734	$46,237

Figure B-4: ***Whole Building Electricity Consumption*** **for post period, February 1992 - June 1994 (Victoria High School)**



B.3.4 Total Monthly Consumption

The total monthly energy consumption is summarized in Table B-2. Again, it is readily apparent that other electric accounts for the majority of this site's electric energy use.

Table B-2 : ***Monthly Energy Consumption*** **(Victoria High School)**

	wbelec kWh/month	chlr #1 kWh/month	other kWh/month	wbheat MMBtu/month
PRE PERIOD				
Jun 91	121,743	0	241,636	16
Jul	137,603	0	220,847	21
Aug	270,742	0	167,456	1
Sep	276,575	0	167,304	18
Oct	242,163	17,072	152,268	16
Nov	160,325	5,118	136,391	45
Dec	150,396	4,642	219,845	597
Jan 92	139,697	1,225	165,440	1,640
Total Consumption	1,499,242	28,057	1,471,186	2,354
Total Cost	$41,799	$782	$41,017	$10,755
POST PERIOD				
Feb 92	149,365	5,518	143,414	775
Mar	141,229	4,906	161,499	664
Apr	190,903	9,330	200,369	326
May	227,078	12,205	244,332	78
Jun	136,443	4,319	203,001	41
Jul	145,357	6,713	182,240	40
Aug	199,450	11,992	142,447	65
Sep	263,715	14,623	139,716	69
Oct	230,083	13,660	153,058	174
Nov	159,136	7,442	171,351	685
Dec	125,653	1,982	211,597	933
Jan 93	134,521	1,253	225,745	1,113
Feb	134,220	2,229	151,229	864
Mar	147,342	5,880	155,418	674
Apr	173,404	9,780	154,491	93
May	194,974	11,349	159,892	89
Jun	128,470	10,102	173,318	59
Jul	20,765	1,629	221,511	9
Aug	153,649	8,711	138,114	49
Sep	233,928	13,954	131,201	86
Oct	211,490	13,750	144,102	108
Nov	135,042	5,710	209,575	258
Dec	116,966	4,896	77,688	276
Jan 94	145,092	3,929	126,914	733
Feb	145,476	4,244	38,909	756
Mar	146,811	6,386	77,542	290
Apr	184,945	9,826	151,400	118
May	222,895	12,802	88,572	104
Jun 94	20,330	1,033	19,297	10
Total Consumption	4,618,730	220,155	4,397,944	9,538
Total Cost	$128,770	$6,138	$122,615	$45,303
Grand Total Consumption	6,117,972	248,212	5,869,129	11,891
Grand Total Cost	$170,569	$6,920	$163,631	$56,059

B.3.5 Average Daily Consumption

Figures B-5a and B-5b depict the average hourly consumption for the semester period and the non-semester period. From both figures, you can see that the consumption for the weekdays does not significantly change in profile, but decreases in magnitude, with more significant reductions in the nighttime hours.

For the semester period, Figure B-5a, the weekday consumption slightly decreased during the daytime hours, 7:00 a.m. to 5:00 p.m., and greatly decreased during the nighttime hours, 5:00 p.m. to 7:00 a.m. The weekend consumption decreased during the nighttime, but increased during the daytime hours. Why does the post consumption exceed that of the pre consumption for weekends? One possible explanation is that the setpoints on the new EMCS are such that the consumption is greater during the weekend than before the EMCS was installed. Another possible explanation is that there are many more data points in the post period, and there are periodic special events on the weekends These two factors combined may result in higher weekend daytime consumption in the post-retrofit period.

For the non-semester period, Figure B-5b, weekday consumption slightly decreased during the daytime hours and greatly decreased during the nighttime hours. Here, the weekend usage decreased in a manner similar to that of the weekdays. The changes in both weekday and weekend consumption can be attributed to the EMCS retrofit.

Tab B-4 contains a summary of the hourly averages and the respective standard deviations and count of data points. The hourly averages are the data that is plotted in Figures B-5a and B-5b. For this site, the standard deviations are quite large. They do not vary much for the hours of 0 through 7, then jump to higher levels in hours 8 through 23. This should not be alarming, because the periods that the data were averaged over include wide ranges of temperatures. As was seen earlier, in Figures B-1 and B-2, the energy usage is temperature dependent. The count of data points represents the actual number of data points used to calculate the average, which corresponds to the amount of time that the equipment was actually operating.

Figure B-5a*: Semester Pre-/Post-retrofit Comparison* **(Victoria High School)**

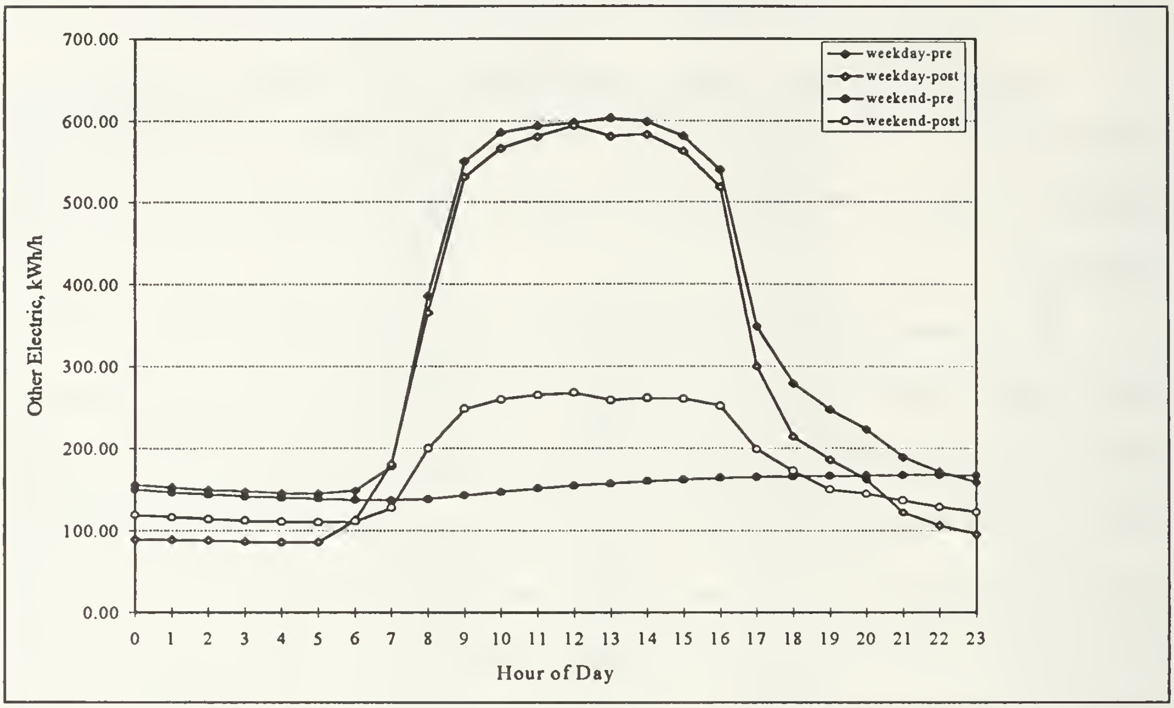
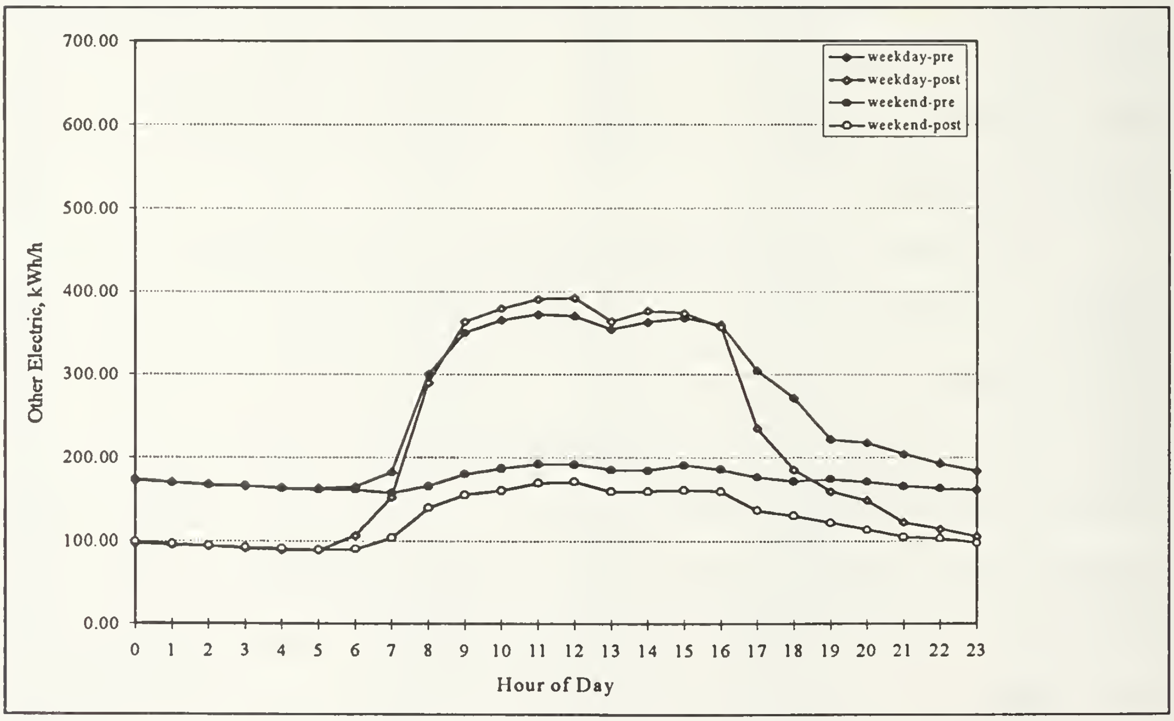


Figure B-5b: *Non-semester Pre-/Post-retrofit Comparison* **(Victoria High School)**



The difference in other electric energy consumption was calculated based on the average daily data. This is shown in Table B-3, both as a difference in energy and a percentage difference in energy.

Table B-3: ***Reduction in Other Electric Consumption*** **based on average daily data (Victoria High School)**

	# days in period	Average Daily Consumption kWh/day	Difference in Average Daily Consumption kWh/period	% Difference in Average Daily Consumption
Semester				
weekday-pre	91	7,877		
weekday-post	394	6,889	-988	-12.54%
weekend-pre	35	3,674		
weekend-post	149	4,245	571	15.54%
Non-semester				
weekday-pre	79	6,159		
weekday-post	241	5,182	-977	-15.86%
weekend-pre	33	4,180		
weekend-post	92	3,017	-1,163	-27.82%

B.3.6 Plots from MECR

The September MECR energy use plots for four years are shown in Tab B-5. These provide a more qualitative look at the effects of the EMCS. September 1991 is a pre-retrofit plot. Note that there is relatively high consumption between the hours of midnight and 6:00 a.m., with a gradual increase to daytime levels. This is followed by a slow decrease in consumption between the hours of 4:00 p.m. and 10:00 p.m. There are many afternoons and evenings where consumption did not drop to nighttime levels. September 1992 shows dramatically reduced nighttime consumption, with a much sharper slope up to daytime levels between 7:00 a.m. and 8:00 a.m. when compared to September 1991. The consumption drops off much more quickly at 4:00 p.m. and the afternoon and evening consumption is drastically reduced as compared to September 1991.. The profiles are slightly improved between the months of September 1992 and September 1993. The profiles are slightly degraded in September 1994, although are still greatly improved when compared to September 1991. The characteristic post-retrofit shape is maintained, but there are many occurrences of increased nighttime consumption.

Overall, the changes seen in the MECR plots can be attributed to the EMCS retrofit.

It should be noted that these profiles only allow a look at weekday data. The weekend data is unreadable from these plots. Separating the data into weekdays and weekends, then plotting separately would enable one to evaluate weekends, as well as weekdays.

B.3.7 Data Summary Notebook Information

The Data Summary Notebook information is included in Tab B-6 for information only. It is not analyzed for this site.

Tab B-1

School District Schedules

VICTORIA PUBLIC SCHOOLS
School Calendar 1993-1994

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
1993 JULY					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21	22	23	24 25	26	27	28	29	30	31	
AUGUST	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	<18	19	20	21 22	23	24	25	26	27	28 29	30	31					10
SEPTEMBER				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28>	<29	30			19
OCTOBER						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30 31	21
NOVEMBER		1	2	3	4>	<5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30					19
DECEMBER				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28	29	30	31		13
1994 JANUARY	1 2	3	4	5	<6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30	31						18
FEBRUARY			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17>	<18	19 20	21	22	23	24	25	26 27	28						19
MARCH			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30	31			17
APRIL						1	2 3	4	5	6	7	8	9 10	11	12	13	14>	<15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30	19
MAY	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27>	28 29	30	31					20
JUNE				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28	29	30			
																															Total	175

Inservice
- September 7-8
- January 4-5
- February 21
- March 11

Workdays
- August 16-17
- January 3
- May 28

Holidays
- July 5 – Holiday
- September 6 – Labor Day
- November 11 – Veteran's Day
- November 24 (1/2)-26 Thanksgiving
- December 17 (1/2)-31 Christmas
- March 14-18 – Spring Break
- April 1-4 – Easter

Bad Weather Days
- April 4
- May 28

Appraisal Period
- 1st Appraisal Period (Level 1) September 1 - January 21
- 1st Appraisal Period (Level 2, 3, 4) September 1 - May 6
- 2nd Appraisal Period (Level 1) January 24 - May 6

No Appraisal Days
- August 18-31
- September 3
- November 10
- November 23-24
- December 16-17
- March 10, 31
- May 9-27

Early Dismissal
- November 24 (Early Release Day)
- December 17 (Early Release Day)

Graduation

Victoria High School	May 26
Stroman High School	May 27

Six Weeks	Begins <	Ends >	
First	August 18	September 28	27
Second	September 29	November 4	27
Third	November 5	December 17	28
1st Semester	August 18 - December 17		82
Fourth	January 6	February 17	31
Fifth	February 18	April 14	31
Sixth	April 15	May 27	31
2nd Semester	January 6 - May 27		93
		TOTAL	175

SCHOOL CALENDAR 1992 - 93

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
1992 JULY				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26	27	28	29	30	31		
AUGUST	1 2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	< 19	20	21	22 23	24	25	26	27	28	29 30	31						9
SEPTEMBER			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28 >	< 29	30				21
OCTOBER					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21	22	23	24 25	26	27	28	29	30	31	22
NOVEMBER	1	2	3	4	5	6	7 8	9 >	< 10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30						19
DECEMBER			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30	31			14
1993 JANUARY						1	2 3	4	< 5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	30 31	19
FEBRUARY		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16 >	< 17	18	19	20 21	22	23	24	25	26	27 28							19
MARCH		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30	31				18
APRIL					1	2	3 4	5	6	7	8 >	9	10 11	12	< 13	14	15	16	17 18	19	20	21	22	23	24 25	26	27	28	29	30		20
MAY	1 2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30	31						19
JUNE			1	2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30				

Total Days 180

Inservice

August 17-18
January 4
Feb. 15 Effective Schools
May 28

Bad Weather Days

April 12
May 29

*Revised 6-92

Holidays

July 4 - Independence Day
September 7 - Labor Day
November 25(1/2)-27 Thanksgiving
December 18(1/2)-January 1 Christmas, New Year
March 15-19 - Spring Break
April 9-12 - Easter

Appraisal Period

1st Appraisal Period (Level 1) September 2 - January 8
1st Appraisal Period (Level 2,3,4) September 2 - May 21
2nd Appraisal Period (Level 1) January 11 - May 21

No Appraisal Days *

August 19 - September 1
November 24
December 14 - 17
April 8
May 3 - 27
(except for 3rd appraisals)

Early Dismissal

September 15
October 12
November 25 (Early Release Day)
December 18 (Early Release Day)
April 28
May 27

Graduation

SHS.....May 27
VHS.....May 28

Six Weeks - Begins		Ends	
First.........	Aug. 19	Sept. 28	28
Second.......	Sept. 29	Nov. 9	30
Third.........	Nov. 10	Dec. 18	27
1st Semester			
August 19 - December 18			85
Fourth.....	Jan. 5	Feb. 16	30
Fifth........	Feb. 17	Apr. 8	32
Sixth.......	Apr. 13	May 27	33
2nd Semester			
January 5 - May 28			95
		TOTAL	180

VICTORIA PUBLIC SCHOOLS
SCHOOL CALENDAR 1991- 1992

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
1991 JULY		1	2	3	[illegible]	5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30	31				
AUGUST					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21	<22	23	24 25	26	27	28	29	30	31	7
SEPTEMBER	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30						20
OCTOBER			1	2	3	4	5 6	7>	<8	9	10	11	12 13	14	15	16	17	18	19 20	21	22	23	24	25	26 27	28	29	30	31			23
NOVEMBER						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18>	<19	20	21	22	23 24	25	26	27	28	29	30	19
DECEMBER	1	2	3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30	31					15
1992 JANUARY				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16>	17	18 19	<20	21	22	23	24	25 26	27	28	29	30	31		19
FEBRUARY	1 2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29							20
MARCH	1	2>	<3	4	5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30	31					16
APRIL				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16>	17	18 19	20	<21	22	23	24	25 26	27	28	29	30			20
MAY						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25	26	27	28	29	31	21
JUNE		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15	16	17	18	19	20 21	22	23	24	25	26	27 28	29	30					

TOTAL DAYS 180

Inservice/Preparation Dates

August 20-21
January 17
March 13 Effective Schools
May 30

Bad Weather Days:

April 20
June 1

Holidays

July 4 - Independence Day
September 2 - Labor Day
Nov. 27 (1/2)-29 - Thanksgiving
December 20 (1/2) January 3
Christmas, New Year
March 16-20 - Spring Break
April 17 - 20 Easter

Appraisal Periods

1st Appraisal Period (Level 1)
September 5-January 10
1st Appraisal Period (Level 2,3, 4)
September 5-May 20
2nd Appraisal Period (Level 1)
January 20-May 20

No Appraisal Days

Aug. 21-Sept. 4
Nov. 26
Dec. 20
Jan. 13-16
April 16
May 21-29

Early Dismissal

October 23
Nov.27 (Early Release Day)
Dec. 20 (Early Release Day)
April 28
May 29

Graduation

VHS....May 29
SHS....May 30

Six Weeks -	Begins	Ends	
First..........	August 22........	October 7	32
Second........	October 8...	Nov. 18	30
Third........:	November 19..	January 16	31
1st Semester	Aug. 22-Jan. 16		93
Fourth.......	January 20....	March 2	31
Fifth..........	March 3.........	April 16	27
Sixth.........	April 21.......	May 29	29
2nd Semester	Jan. 20-May 29		87
		Total	180

Revised June 20, 1991

VICTORIA PUBLIC SCHOOLS
SCHOOL CALENDAR 1990 - 91

	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	M	T	W	TH	F	S/S	
JULY	1	2	3		5	6	7 8	9	10	11	12	13	14 15	16	17	18	19	20	21 22	23	24	25	26	27	28 29	30	31					
AUGUST				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26							
SEPTEMBER	1 2		<4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30							19
OCTOBER		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15>	<16	17	18	19	20 21	22	23		25	26	27 28	29	30	31				23
NOVEMBER					1	2	3 4	5	6	7	8	9	10 11	12	13	14	15	16	17 18	19	20	21			24 25	26>	<27	28	29	30		20
DECEMBER	1 2	3		5	6	7	8 9	10	11	12	13	14	15 16	17	18	19			22 23						29 30							13
JANUARY				2	3	4	5 6	7	8	9	10	11	12 13	14	15	16	17	18	19 20	21>		<23	24	25	26 27	28	29	30	31			21
FEBRUARY						1	2 3	4	5	6	7	8	9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24	25		27	28			20
MARCH						1	2 3	4>	<5	6	7		9 10	11	12	13	14	15	16 17	18	19	20	21	22	23 24						30 31	15
APRIL		1	2	3	4	5	6 7	8	9	10	11	12	13 14	15		17	18	19	20 21	22>	<23	24	25	26	27 28	29	30					22
MAY				1	2	3	4 5	6	7	8	9	10	11 12	13	14	15	16	17	18 19	20	21	22	23	24	25 26		28	29	30	31>		22
JUNE	2	3	4	5	6	7	8 9	10	11	12	13	14	15 16	17	18	19	20	21	22 23	24	25	26	27	28	29 30							

Total Days 175

Inservice

August 27-31
January 22
March 8 - Optional Inservice
June 1

Bad Weather Days:

Instruction.........June 3; June 4
Inservice/Preparation...June 5

Holidays

July 4 - Independence Day
September 3-Labor Day
November 22-23 - Thanksgiving
December 20-31, Christmas
January 1 New Year
March 25-29 Spring Break
May 27 - Memorial Day

Reporting Periods

First Semester Begins ...September 4
First Semester Ends ......January 21

Second Semester Begins..January 23
Second Semester Ends...........May 31

No Appraisal Days

Sept. 4-14	Jan. 2, 14-18
Nov. 21	Mar. 22
Dec. 19	May 23-31

Early Dismissal

October 24
December 4
February 26
April 16
May 31

Graduation

Victoria H.S...........June1
Stroman H.S...........May 31

Six Weeks - Begins		Ends	
First..........	September 4	October 15	30
Second.......	October 16...	November 26	28
Third.........	November 27.	January 21	31
		1st Semester	89
Fourth.......	January 23...	March 4	29
Fifth..........	March 5..	April 22	29
Sixth.........	April 23........	May 31	28
		2nd Semester	86
		Total	175

Tab B-2

Audit Technical Analysis

TECHNICAL ANALYSIS OF FACILITY

ECRM DESCRIPTIONS AND CALCULATIONS

Facility Name: All Schools

ECRM No.: 1

ECRM Name: Energy Management System

a. Summary

Kwh savings:	1,583,682	Kwh/yr
Demand savings:	898	KW-mo/yr
MCF savings:	3,850	MCF/yr
Cost savings:	$95,254	/yr
Implementation cost:	$380,980	
Simple payback:	4.0	years

b. Description

On/Off and temperature control in all of the Victoria ISD schools addressed in this report are inadequate. Typically, on/off controls consist of a) 7-day timeclocks which are controlled manually, b) manual control at thermostats or wall switches, and c) programmable thermostats in a very few locations, installed in the last two years. The great majority of on/off control is performed manually, with the result that operating hours are excessive in every school. There is not a single school addressed in this report where on/off control for the majority of HVAC equipment is performed automatically.

Timeclock controls were installed many years ago and are not suited for the needs of the schools.

- There is no way to enforce rigorous hours of HVAC operation if the custodial staff has access to all timeclocks. Even if the timeclocks were functioning with their trippers and the timeclock cabinet were locked, override timers on the face of the timeclock cabinets would allow custodians to turn on HVAC units. The custodians work typically until 9 PM. The natural human tendency is to keep the units on to maintain most comfortable working conditions. Custodial staffs have been instructed on several occasions by the VISD maintenance staff to turn off HVAC promptly after school. Without direct and continuous supervision, one cannot reasonably expect the custodial staff to do so. And they don't.
- The timeclocks offer little flexibility. They typically control multiple HVAC units on one circuit. Often, an entire bank of HVAC units operates when in fact not all are needed. Special events may at time be held outside of normal operating hours. The existing override timers also control banks of units, so -- if the timeclocks and override timers were even used -- more units would operate than necessary.
- There is no feedback with the timeclock system, such as space temperature or humidity readings, and actual operating status of the unit. In several cases, air conditioning takes place 24 hours per day in order to prevent humidity-related problems. Also, heating units may be left on overnight when weather is cold, maintaining temperatures at comfort conditions. Feedback information on space versus outdoor conditions could save a great deal of energy by reducing operating hours.

Summer operation of HVAC systems is also excessive. Schools are cleaned over a period of several weeks during each summer. Depending upon school size, the number of people cleaning, whether summer school is held or not, and the type of cleaning projects taking place, the cleaning process can take up to 6 weeks or more. Often the cleaning crews will turn on air conditioning for entire schools or wings of schools, regardless of how many rooms are actually being cleaned, since the method of turning units on is to flip a master timeclock switch which turns on whole banks of units. Again, virtually all control is manual through thermostats or timeclock master trippers. In addition to air conditioning schools for personal comfort, the cleaning crew operates the air conditioning to speed up drying of floors and other surfaces cleaned. Also, some teachers start coming to school by mid August. Typically, air conditioning throughout an entire school is again turned on, even though the number of teachers occupying the school is very small.

Temperature controls are virtually all open to occupant adjustment. The number of locking thermostats in all schools addressed in this report can be counted on one hand, and some of those are not locked. Typical settings are in the low 70's (deg F).

Even the programmable thermostats of the most recently installed HVAC units offer less than ideal control. The units inspected were programmed for 6 AM to 6 PM operation. While this schedule covers most occupancy demands, it is generally excessive. Neither teachers nor staff reprogram the thermostats as their occupancy needs differ.

Though the quantity of timeclocks and HVAC units may vary by school, the control methodology described above is typical of all the schools in this report. Controls in each school are addressed individually below. A summary of On/Off times follows (as determined by interviews with custodial staffs), starting on page 80.

Aloe Elementary

There are four timeclocks located in a small janitorial room in the main wing. Each is a 7-day timeclock. Clock #1 controls the library unit, #2 the kitchen, #3 the offices and classrooms, and #4 the cafeteria units. There are override toggle switches in the face of the timeclock cabinet, one for each timeclock. However, as the timeclocks are not used as originally intended, the overrides are useless. On each timeclock, on/off trippers have been removed, and the custodial staff uses the master on/off tripper to control units. All units are turned on manually by custodians at about 6:30 - 7:00 AM. The custodial staff works after school until 9 PM, and turns the units off when they leave.

In the 3rd/4th grade wing and the kindergarten wing, programmable thermostats have been installed. On/off times are 6 AM to 6 PM, Monday through Friday.

De Leon Elementary

There are two timeclock stations in the school. The first station, located behind the library, has four 7-day timeclocks. The second station, located in an electrical room in the south classroom wing, has three 7-day timeclocks. There is an override toggle switch for each timeclock. These seven timeclocks control the seven rooftop HVAC units installed with the original school. HVAC units 8 - 11 were added with the new classroom addition. They are controlled directly from individual room thermostats, not by timeclock.

All units are controlled manually by the custodial staff using the timeclock master on/off tripper, and room thermostats. Operating hours are from 6 AM until 8 PM.

Dudley Elementary

There are three 7-day timeclocks located in the electrical room across the hall from the cafeteria. The first controls classroom and office units, the second the kitchen, and the third the cafeteria. All units are controlled manually by the custodial staff using the timeclock master on/off tripper. On/off hours are typically 7 AM to 7 PM, Monday through Friday.

Hopkins Elementary

There are four rooms which contain timeclocks at Hopkins. The main mechanical room has four 7-day timeclocks, controlling direct expansion units for 1) the office area, 2) the library, 3) the kitchen, and 4) the cafeteria. There is a single 7-day timeclock in the north wing, one in the south wing, and one in the middle wing. Each controls HVAC fan-coil units and chillers/pump for their respective wing. Most or all trippers have been removed from all timeclocks, and all are operated manually.

All units are turned on manually by custodians at about 6:00 AM. The custodial staff works after school until 9 PM, and turns the units off when they leave.

Howell Intermediate

There is a main control panel at Howell Intermediate located in the main mechanical room. Toggle switches are located in the face of the panel for controlling virtually all HVAC units in the school. When the custodian arrives at 6:30 AM, he turns on all HVAC units via the toggle switches, and the chiller if necessary. He always turns on the boiler, no matter what the weather conditions, since the HVAC system at Howell is reheat. Another custodian turns off HVAC equipment around 7 PM.

In summer, the same procedure is followed for the approximately six weeks cleaning period.

Juan Linn Elementary

All HVAC units installed with the 1986 addition are controlled by programmable thermostats. Programmed on/off times are 6 AM on, and 6 PM off, Monday through Friday. The one exception is the library unit. It has a programmable thermostat, but the unit remains in operation continuously out of concern for mildew on library books. The two rooftop units over the original (east) classroom wing have been replaced recently, and are controlled by programmable thermostats also.

All fan-coil units and the chiller of the stand-alone 1951 addition are controlled by 7-day timeclock located by the east entrance to the building. All trippers to the clock have been removed. The janitor operates the master timeclock tripper to control HVAC.

In the main building, the custodian turns units on manually at the thermostats when she arrives at 6:45 AM, and another custodian turns units off around 8 PM.

Summer school is held in Juan Linn for six weeks. Again, custodians turn equipment on/off manually. However, most units are turned off earlier in the day as compared to the regular school year.

O'Connor Elementary

Two rooms contain 7-day timeclocks at O'Connor, one in the north wing and one in the south. All units are turned on manually by custodians at about 6:30 AM, and off at around 8:00 PM. The east wing addition units are controlled manually by custodians via their thermostats.

There are two locking thermostats in the north wing, but neither was locked when seen.

Shields Elementary

The majority of floor area in Shields is served by hydronic fan-coil units. Control is the same as in all other elementaries: 7-day timeclocks exist, but custodial staff uses only the master trippers to turn units on and off when they arrive and depart. Units are turned on around 7 AM, and off about 6:30 PM.

Stanly Elementary

Control of HVAC units in Stanly is identical to O'Connor. The two schools originally had identical floor and HVAC plans. Timeclocks are located in exactly the same rooms as in O'Connor.

Stroman High School

Control of HVAC units at Stroman requires very intensive footwork. The custodian makes rounds to every air handling unit, most fan-coil units, many direct expansion units, and the chiller/boiler/auxiliary equipment each morning around 6:45 AM, where he turns equipment on. Another custodian makes a similar round at about 8:30 PM to turn equipment off.

The kitchen staff turns kitchen HVAC on and off. The coaching staff turns athletic building HVAC off, and the custodial staff turns it back on in the morning, though often the coaching staff forgets to turn units off.

A small (46 ton) reciprocating chiller is located adjacent to the four story Unit A. This chiller is piped to serve only Unit A. During summer and after school hours, parts of Unit A (which contains administrative offices) are the only occupied portions of the school. At 4:30 PM during the school year, the absorption chiller is shut down and the reciprocating chiller is turned on, and continues to operate until 9 PM. In summer, the reciprocating chiller is turned on 7:00 AM, and off at 6:00 PM, unless the main chiller is operating.

Direct expansion split systems serving the Band hall are thermostatically controlled, but are left in operation continuously, summer and winter. If the main air handler serving Band has been shut off and indoor temperature starts to rise, the DX units will maintain humidity and temperature conditions. These backup DX units were installed out of concern for humidity-related problems with Band instruments.

Summer cleaning of the high school takes about 5 to 6 weeks. During this time, the main absorption chiller operates every day, and virtually the entire school is cooled. Cleaning is finished by mid- to late-July, and only the reciprocating chiller operates after that.

Victoria High School

Victoria High is another school requiring intensive footwork in turning HVAC systems on and off. The VHS campus contains numerous buildings spread out over a wide geographical area. The maintenance man starts his round at 7 AM to all mechanical rooms and thermostats/wall switches, turning on equipment. As at Stroman, the coaching staff is responsible for turning off some athletic building HVAC equipment (though they often forget) and the maintenance man turns it back on in the morning.

There are two rooftop units over the Learning Resource Center. During the regular school year, these operate from 7:15 AM until 4 PM. During summer, one of the units is shut down, but the other remains in operation 24 hours per day to prevent problems with mildew. Starting in September, HVAC for the boys dressing room is left on continuously until cold weather hits, so as to reduce odor problems which are worsened by heat and humidity.

Summer school is held in the Academic Wing of VHS, and occasionally in the main wing. The Academic Wing is served by the absorption chiller. The chiller is turned on at 6:30 AM, and off at 1:30 PM. The fan-coil units served by the chiller remain in operation continuously, both summer and winter. The on/off switches for them are located inside the units.

Fan-coil units for the main building are controlled by toggle switches mounted on the wall of each classroom. Teachers are supposed to turn these units off as they leave each day, and the maintenance staff turns them back on in the morning. However, as often as not, the fan-coil units are left on at night.

This ECRM calls for the installation of a direct digital control-based energy management system (EMS) for each school addressed in this report. The EMS will control all HVAC equipment, measure exterior and interior space temperatures, and measure humidity in one or two critical locations within each school. The EMS will have no override timers that custodial staffs can activate. Operating hours of all HVAC units will be determined by the maintenance staff, and controlled by that staff from its central headquarters via modem. (Floor plans on pages 27 through 37 show locations of the units to be controlled, and the proposed locations of new DDC controllers).

Tab B-3

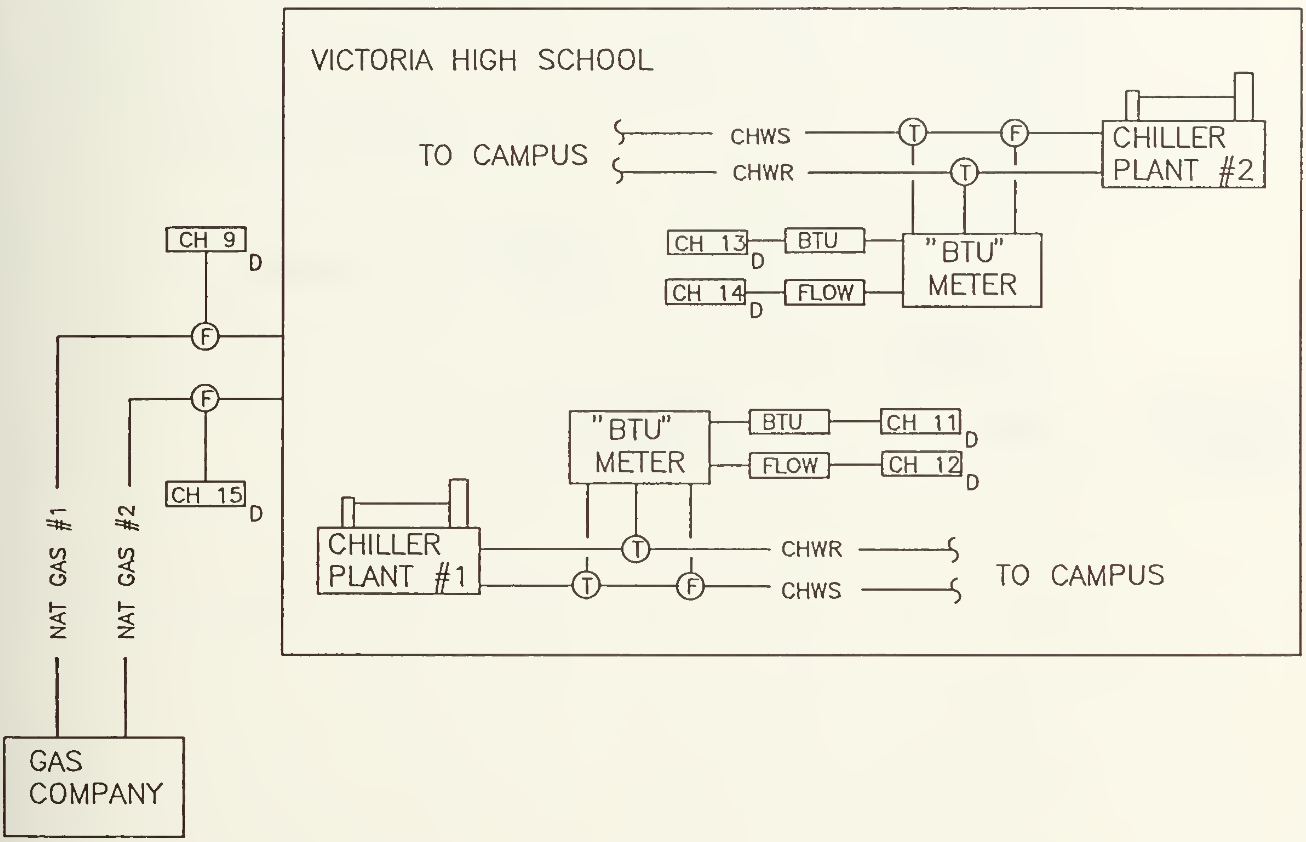
Monitoring Diagrams

THERMAL MONITORING DIAGRAM

VISD – VICTORIA HS

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



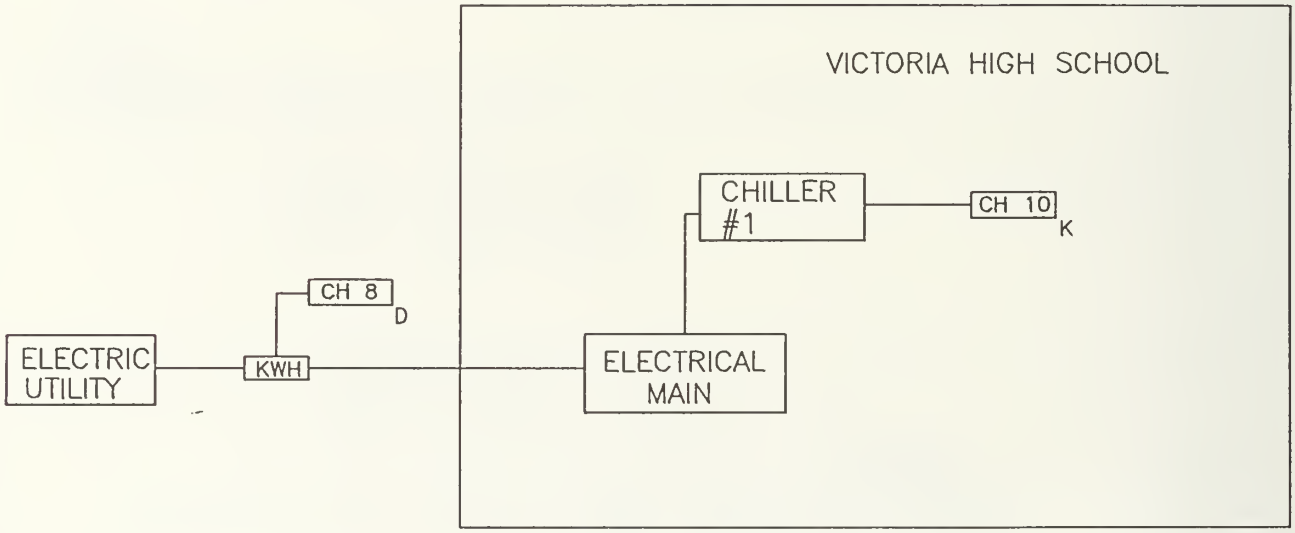
VISD/VICTORIA HS – SITE 127

ELECTRICAL MONITORING DIAGRAM

VISD – VICTORIA HS

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL



VISD/VICTORIA HS – SITE 127

Tab B-4

Average Hourly Data & Related Statistics

Hourly Average

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	155.8478	152.7411	149.7756	147.4356	145.5722	144.9667	148.6356	177.9144	385.7067	550.3722	585.8678	593.8933	597.5478	602.9189	598.7422	580.9522	540.2400	348.3775	279.1622	247.2538	223.2769	189.3615	171.3736	158.8582
1-B-S	89.3124	88.7661	88.2294	86.6309	85.5415	85.8901	112.8985	181.1843	365.0458	531.4911	566.4124	580.8182	594.3167	580.8433	583.0823	563.0736	518.8949	300.1294	213.9661	186.2623	162.1997	121.8235	106.1149	95.6559
0-A-S	150.2361	146.3556	143.7796	141.6625	139.8533	138.3639	137.2004	136.4774	137.9741	142.5008	146.4912	150.8502	154.5609	157.1383	159.6657	162.0158	163.8940	165.0974	165.7601	166.4178	166.8171	167.0696	167.0926	166.8375
0-B-S	118.9952	116.2991	113.6498	111.7100	110.4886	109.5664	111.0122	127.6799	199.8214	247.9293	259.5539	265.1860	267.7734	258.7105	261.2576	260.1428	251.5694	198.8821	172.4642	149.8079	144.5210	136.1297	129.0083	122.3419
1-A-NS	172.7456	170.4848	168.6785	166.1165	164.7354	163.7266	165.6051	183.2089	300.4506	350.5038	365.7974	372.1628	370.3848	354.2342	363.2329	367.9722	360.2241	304.8911	271.6025	222.2127	218.0772	204.7570	193.1266	184.1709
1-B-NS	97.7263	95.5989	94.2586	91.8952	90.2855	89.5016	106.9328	153.1672	289.3108	363.5968	379.4683	390.7246	392.4877	364.0722	376.6465	374.0893	357.0952	235.5791	185.8909	160.1214	149.8390	123.3888	114.9471	105.7818
0-A-NS	174.2824	170.3676	167.7176	166.9412	163.7588	161.9176	162.1382	158.1500	166.3118	180.6618	187.4824	192.5853	191.9941	186.0559	185.1794	191.2294	186.4765	176.6912	171.9794	174.5441	171.4471	166.3059	163.8735	161.7118
0-B-NS	100.2916	97.1494	94.6988	93.1651	91.8386	89.9723	91.0494	104.5373	140.1843	156.4614	161.0373	169.7205	171.7169	159.8964	160.3843	161.6373	160.2265	137.1976	131.0952	122.8687	114.0325	105.5627	103.6549	98.2373

Standard Deviation of the Hourly Average

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	67.9273	65.8407	64.4460	64.0302	62.1425	63.0211	76.6243	84.8685	143.0978	160.0605	164.0983	167.0280	176.4669	178.2542	185.3368	182.8285	171.0840	93.8461	83.8911	73.0449	74.9759	74.2153	57.0681	49.9828
1-B-S	21.6861	23.2511	21.8800	20.4019	19.7393	18.2540	42.1464	89.9723	146.9820	182.8566	194.2151	202.4603	205.4641	204.4085	212.6136	201.7983	192.0298	90.9103	54.4984	53.8733	55.5336	53.0611	33.8103	23.5994
0-A-S	43.5057	43.0013	42.3353	41.7549	41.0891	40.3630	39.8338	39.6245	42.3022	52.9168	60.5251	66.5132	70.8013	73.7412	76.0021	77.8402	78.8368	79.0945	79.1357	79.0952	79.0873	79.2978	79.4792	79.4952
0-B-S	66.4774	65.5404	64.2651	63.3212	62.2459	61.8243	63.8720	80.7031	159.2085	210.6429	225.3422	230.1577	239.1506	235.4430	236.0238	233.4913	219.4059	143.1721	118.8526	98.5710	91.7394	84.1196	78.5033	75.1915
1-A-NS	86.0271	83.9045	81.7709	80.8673	78.9099	78.3911	82.2422	98.1746	159.6581	197.3159	210.9832	215.4262	225.4947	217.6331	219.4239	221.8663	208.0452	152.2857	134.0336	121.7042	111.2659	105.3279	100.6155	97.3309
1-B-NS	24.3434	24.8851	25.1825	23.1370	22.0268	20.5988	43.2421	92.3067	192.8601	252.2756	261.3779	268.5710	270.0534	268.7850	270.7709	263.0763	252.2683	123.5556	80.5049	61.5697	53.8798	42.1642	37.1048	29.9683
0-A-NS	87.5901	86.1269	83.8935	81.0950	79.3833	79.1197	76.3466	76.0481	82.0064	108.2841	113.6487	112.1341	113.8832	104.7284	101.6120	105.0255	105.8376	80.8195	80.1987	76.6572	74.3330	76.4056	75.2121	73.0585
0-B-NS	33.3462	31.3063	29.9837	28.7899	28.6849	26.9378	27.4354	47.3277	121.3100	163.0854	171.2064	176.9169	178.1092	163.9776	165.1637	163.7218	155.3629	86.2512	68.1023	59.6414	47.6750	35.4916	32.1089	29.4605

Count of Data Points

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	89	90	91	91	91	91	91
1-B-S	394	395	395	395	395	395	395	395	395	395	395	395	395	395	395	394	393	395	395	395	395	395	395	395
0-A-S	36	72	108	144	180	216	252	288	324	360	396	432	468	504	540	576	612	648	684	720	756	792	828	864
0-B-S	229	228	229	229	229	229	229	229	229	229	228	228	229	229	229	229	229	229	229	229	229	229	229	229
1-A-NS	79	79	79	79	79	79	79	79	79	79	78	78	79	79	79	79	79	79	79	79	79	79	79	79
1-B-NS	186	186	186	186	186	186	186	186	186	186	186	187	187	187	187	187	187	187	187	187	187	187	187	187
0-A-NS	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
0-B-NS	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	82	83

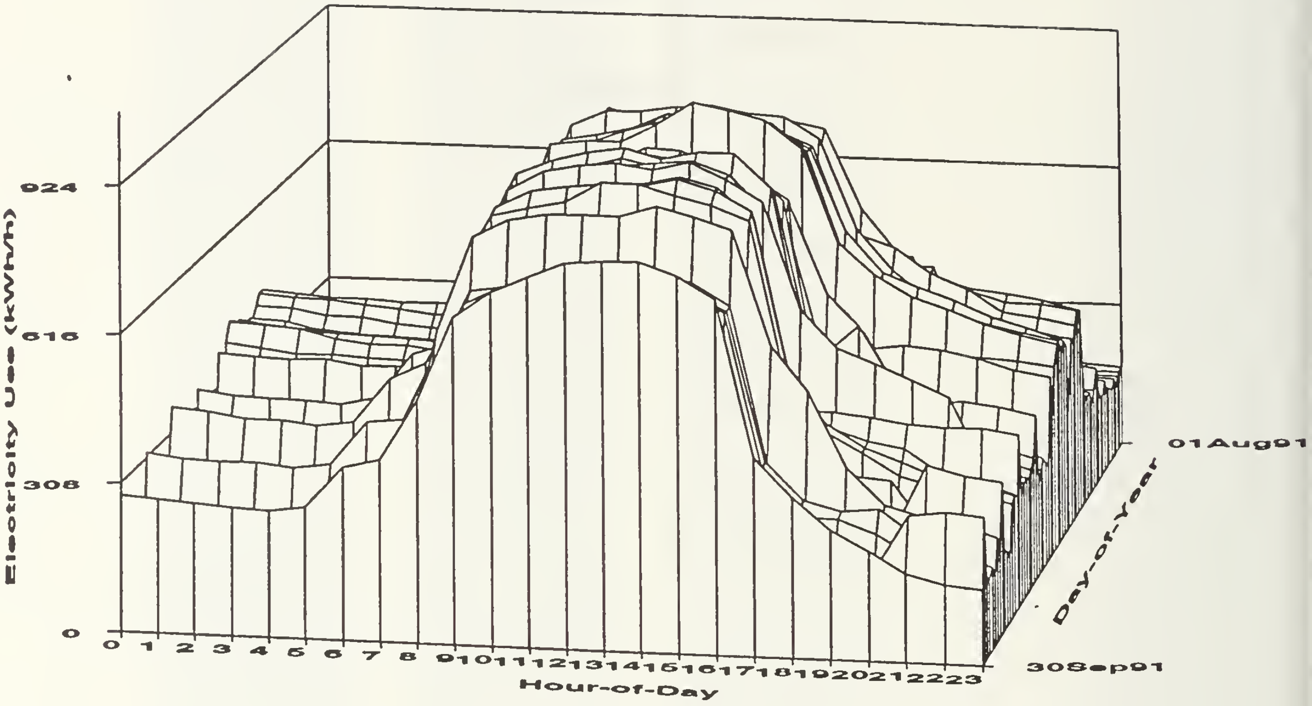
Key

1-A-S	=	Semester/Weekday/Pre-Retrofit
1-B-S	=	Semester/Weekday/Post-Retrofit
0-A-S	=	Semester/Weekend/Pre-Retrofit
0-B-S	=	Semester/Weekend/Post-Retrofit
1-A-NS	=	Non-Semester/Weekday/Pre-Retrofit
1-B-NS	=	Non-Semester/Weekday/Post-Retrofit
0-A-NS	=	Non-Semester/Weekend/Pre-Retrofit
0-B-NS	=	Non-Semester/Weekend/Post-Retrofit

Tab B-5

MECR Plots

Whole–Building Electric



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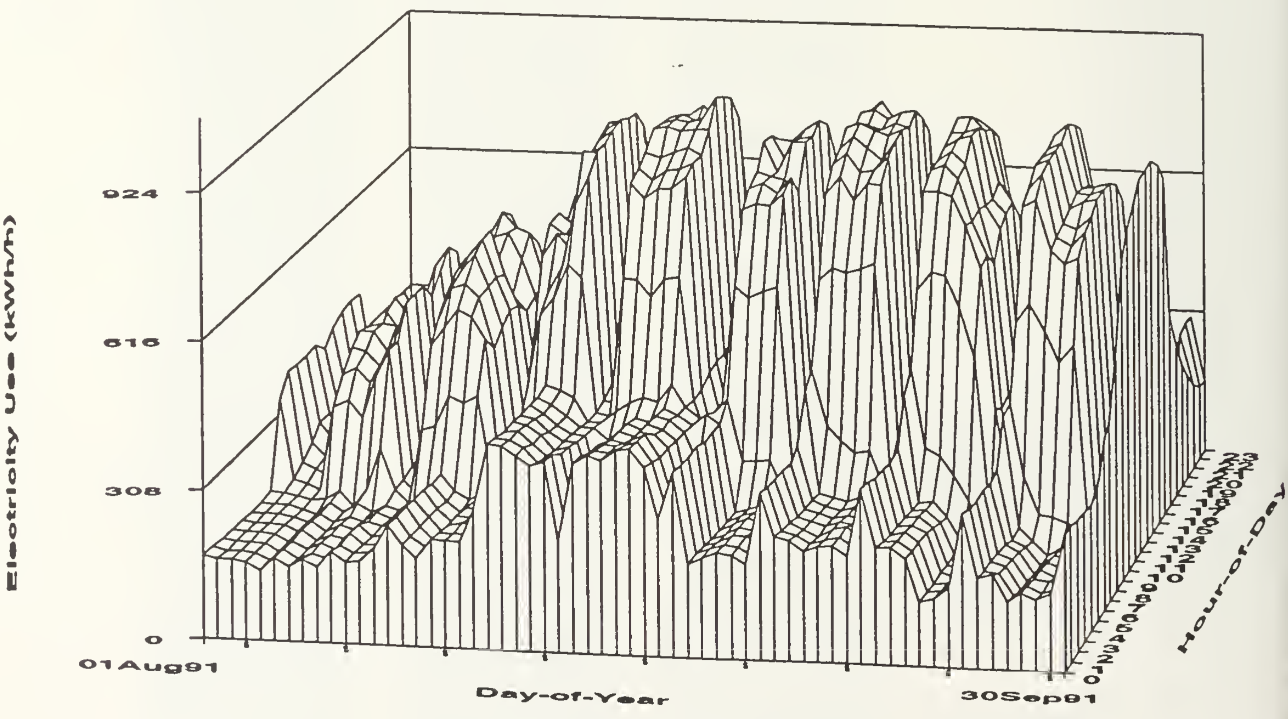
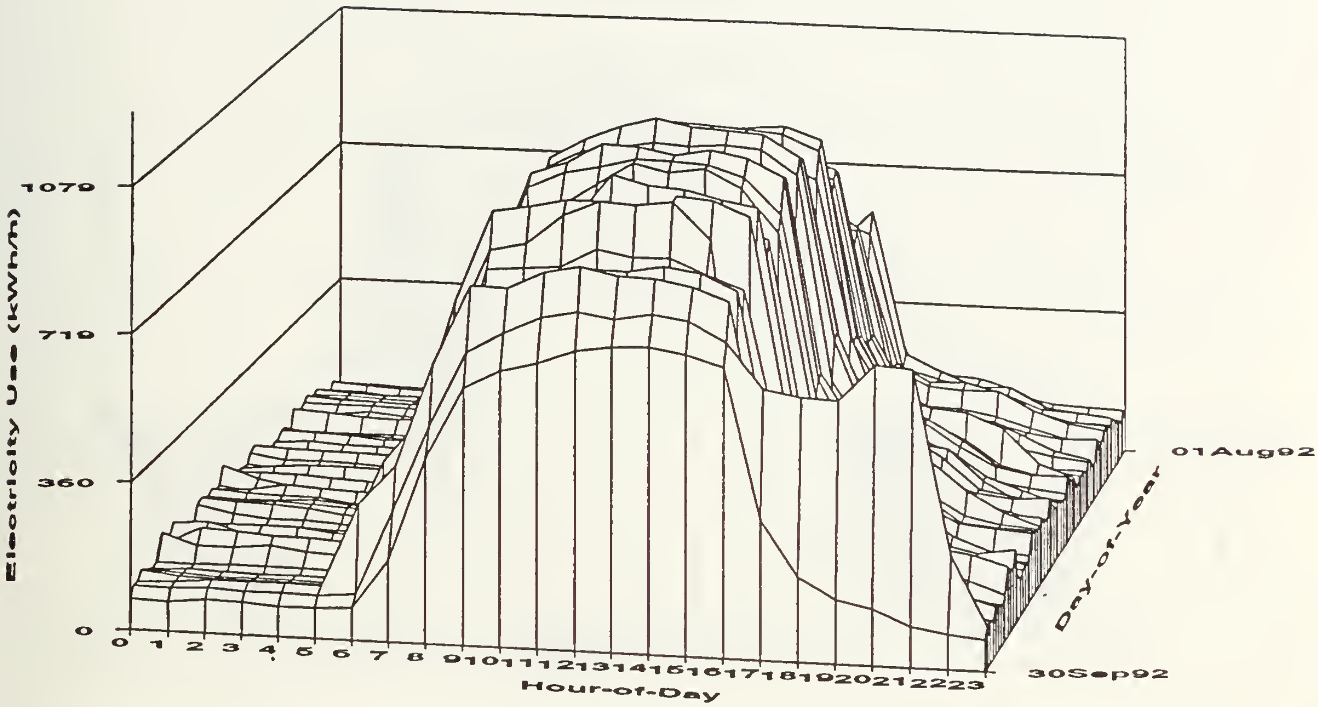


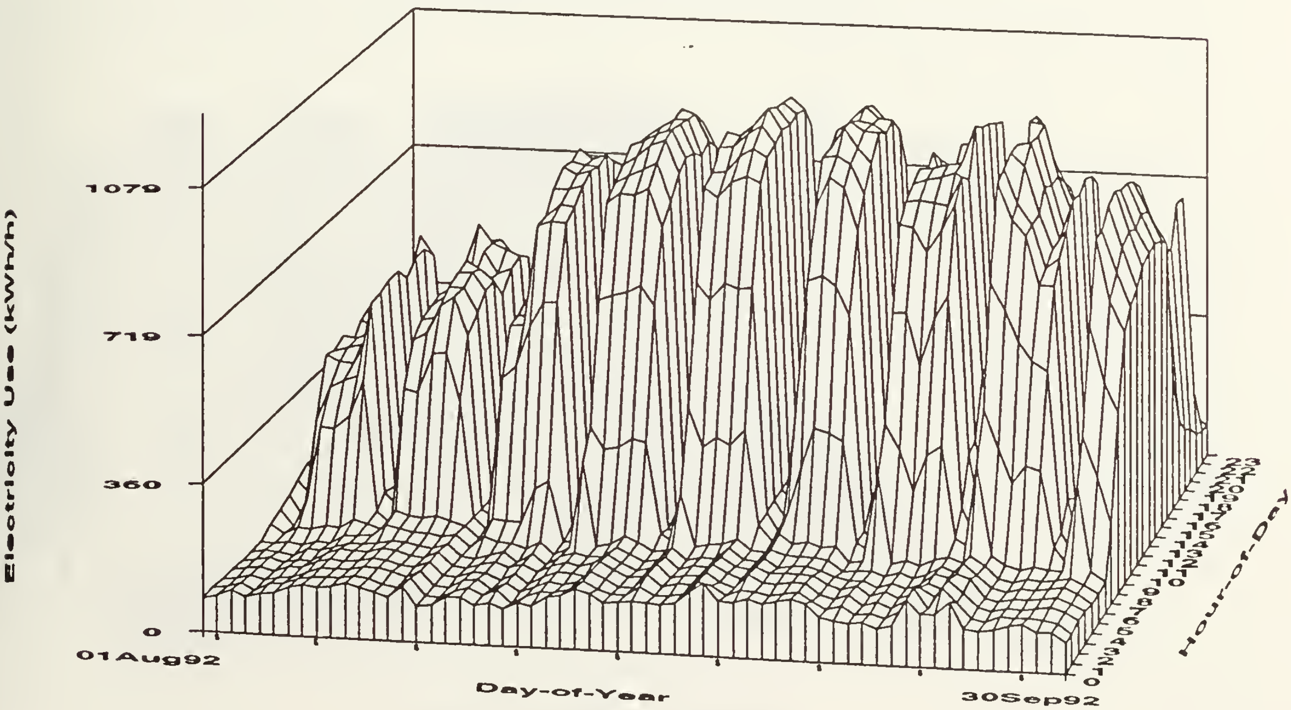
Sundays are marked with an "S"

Victoria High School - Victoria ISD - September 1991

Whole–Building Electric



Whole–Building Electric



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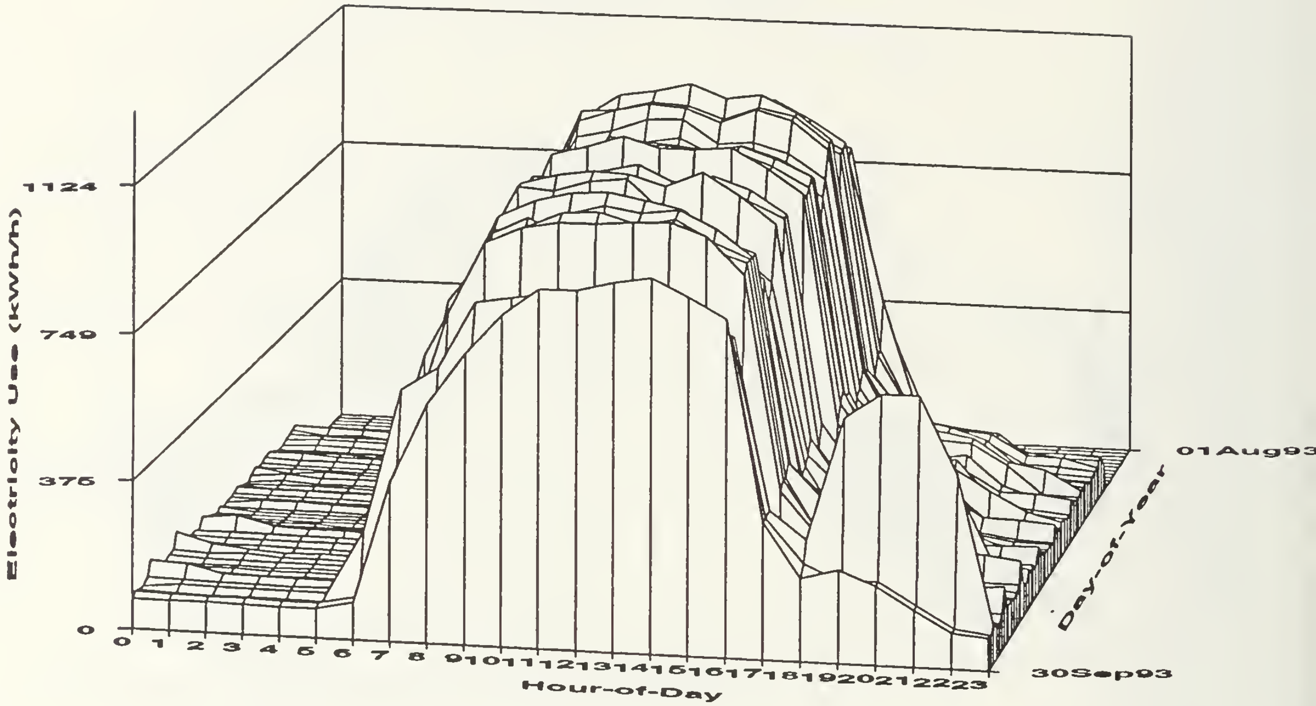
Victoria High School - Victoria ISD - September 1992

Whole–Building Electric



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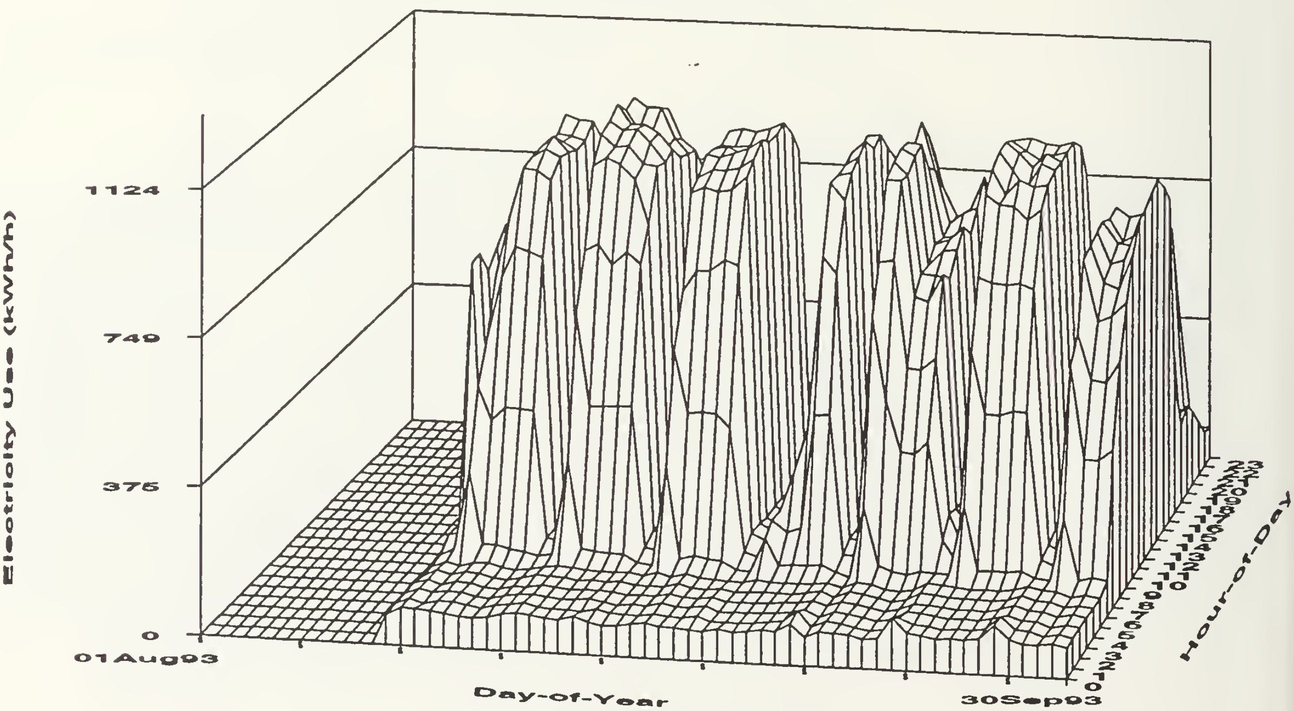

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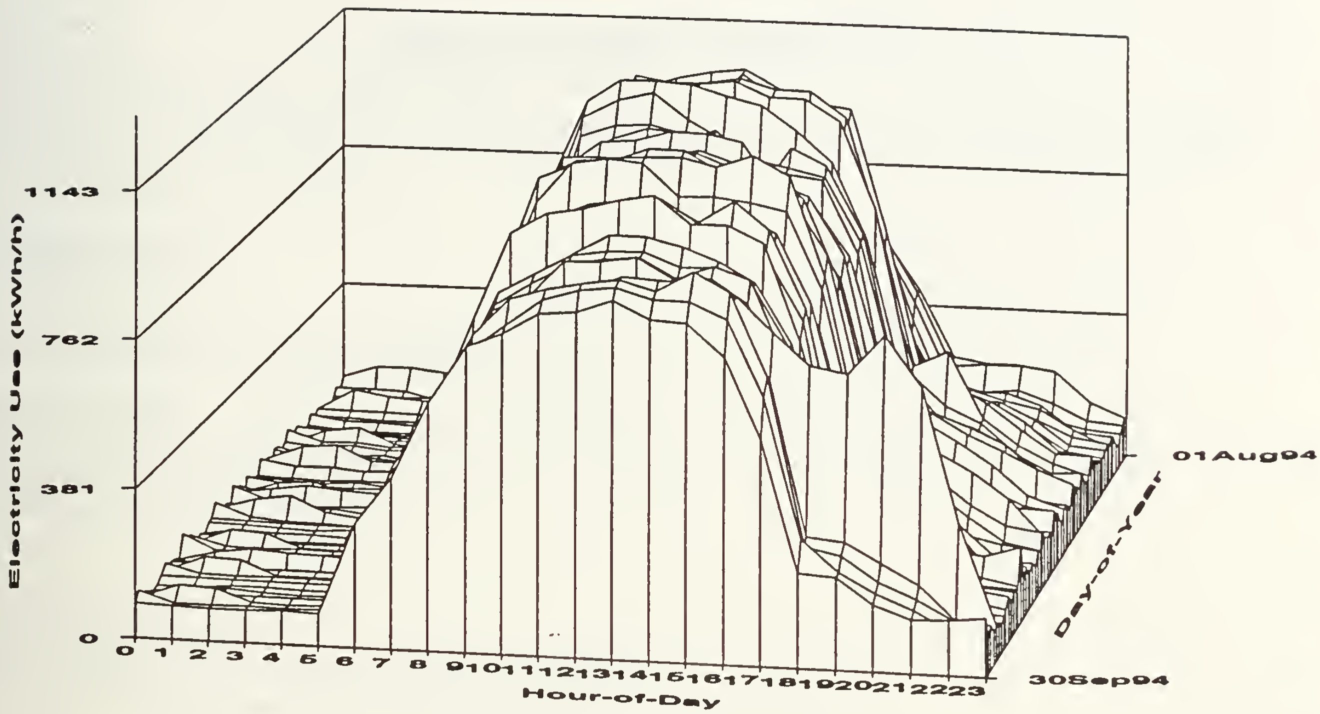
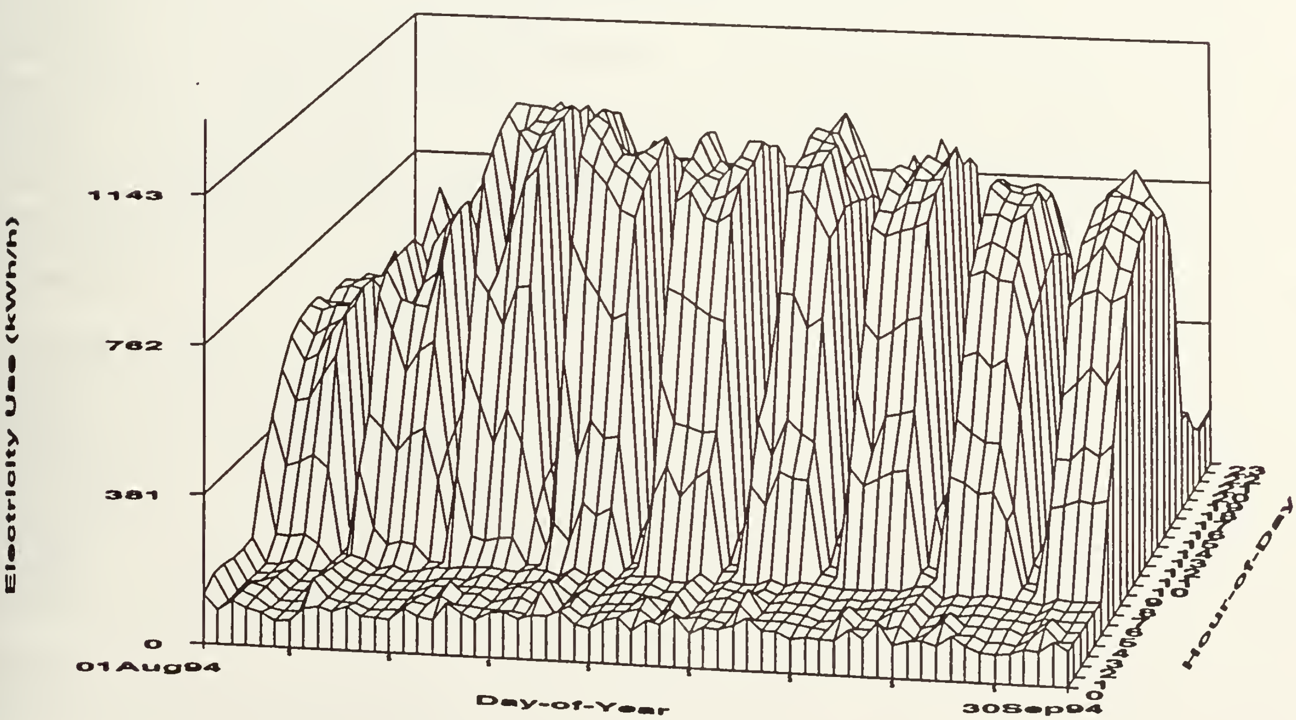
Victoria High School - Victoria ISD - September 1993

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

Victoria High School - Victoria ISD - September 1994

Tab B-6

Data Summary Notebook Information

VICTORIA INDEPENDENT SCHOOL DISTRICT
Victoria High School

Building Envelope:
- 257,000 sq.ft.
- Main Building: Two stories, brick slab, and grade construction with flat roof, 54,000 sq ft.
- Academic Building: same as Main Building, 60,700 sq ft.
- Field house (dressing room, 2-shop buildings, gymnasium, special education building, learning resource center, home economics building, a multi-purpose building with kitchen, cafeteria, band hall and choir room are all one story.), 142,300 sq ft.

Building Schedule:
- 7 am to 4 pm (M-F)

Building's HVAC & other equipment:

Main building:
- 17 rooftop units (4 - 7.5 tons)
- 70 fan-coil units each 0.17hp
- 1-192 ton Trane centrifugal chiller
- 1 boiler

Academic Wing:
- 1-25% O.A 7.5hp AHU
- 112 - 0.05hp fan-coil units and 6 - 0.17hp fan-coil units
- 1-182 ton York centrifugal chiller (replaced absorption chiller in Aug 91)

Field House
- boys dressing room: 8 rooftop units (2-5 tons and 4-7.5 tons).
- Vocational: rooftop unit
- Industrial Arts: 2 rooftop units (15 tons each).
- Gymnasium: 1 rooftop unit (3.0 tons) and 1 steam boiler.
- Home Economics: 1 rooftop unit (15 tons).
- Kitchen: 1 rooftop unit (7.5 tons).
- Cafeteria: 1 rooftop unit (7.5 tons).
- Band Hall: 3 rooftop units (1-10 tons and 1-5 tons).
- Choir: 3 rooftop units (1-5 tons).
- Special Education: rooftop unit (7.5 tons).
- Learning Resource Center: 2 rooftop units (15 tons each).

Auxillary Equipment:
- 2 CHWPs, 1 of 25 hp, 1 of 20hp
- 2 CWPs, 1 of 25 hp, 1 of 15 hp
- 2 Cooling towers, 1 of 15hp, 1 of 20 hp
- 1 HWP of 5hp
- 1 Brine pump
- 1 Refrigerant pump
- 2 Boilers
- 10 Exhaust fans (1/2 hp each)

Lighting:
- Mostly fluorescent (Total load 260 kW).

HVAC Schedule:

- HVAC equipment is turned on manually at 6:00 a.m. and turned off at 8:00 p.m. on weekdays.

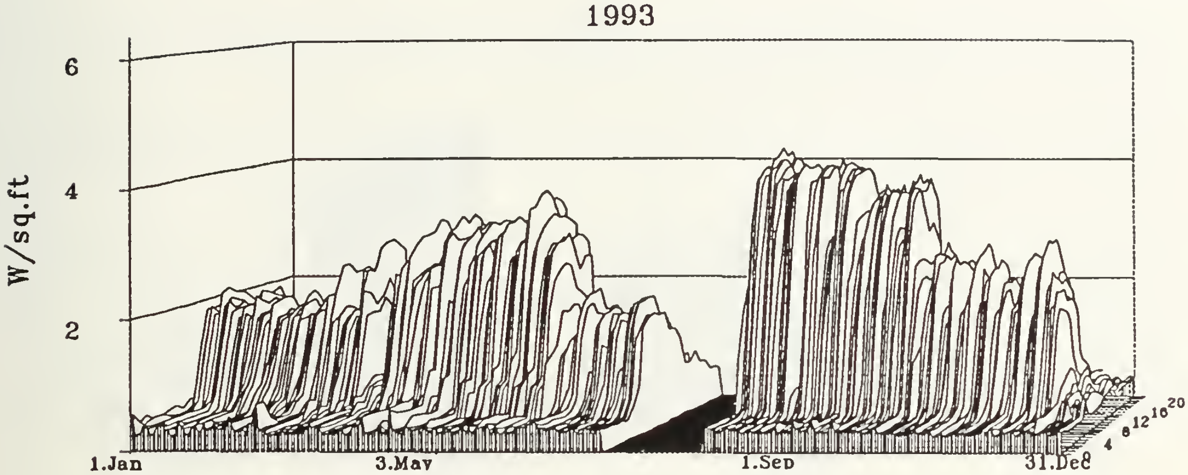
Proposed Retrofits:

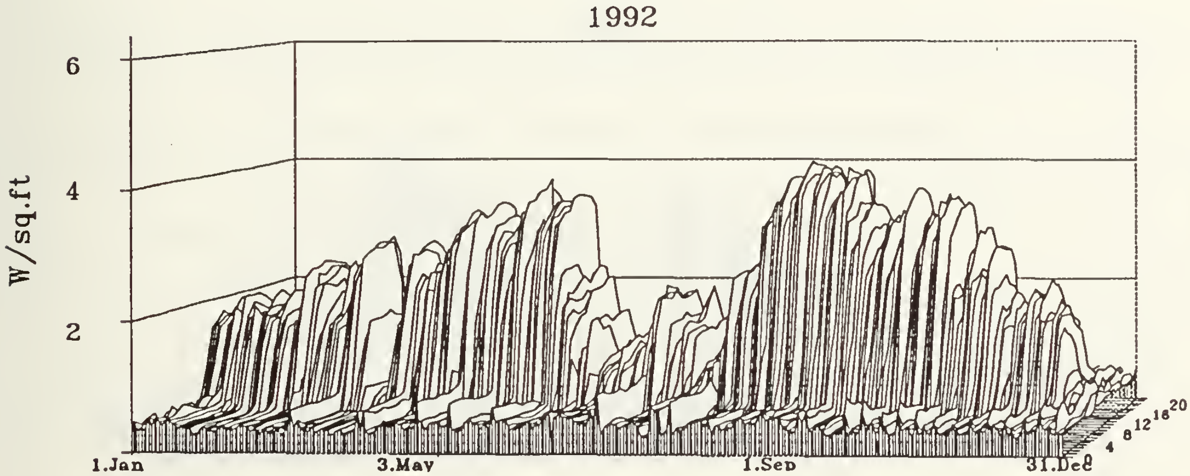
- Energy Management System
- Replace Absorption chiller

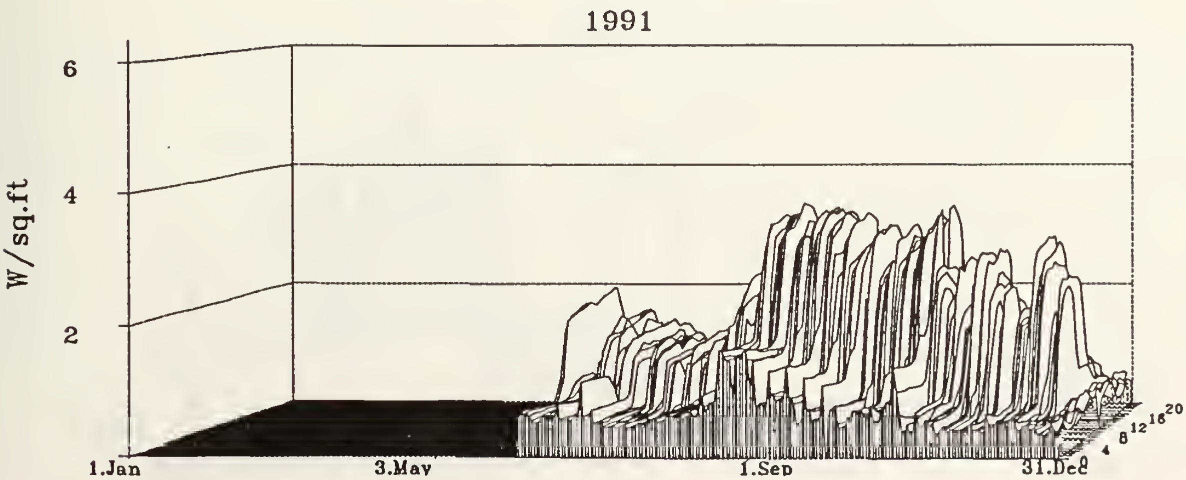
Date of Retrofits:

- Replacement of absorption chiller was completed in August 1991, while work on the other retrofit was completed in January 1992.

Victoria High School (VHS)
W.B. Electric as W/sq.ft.

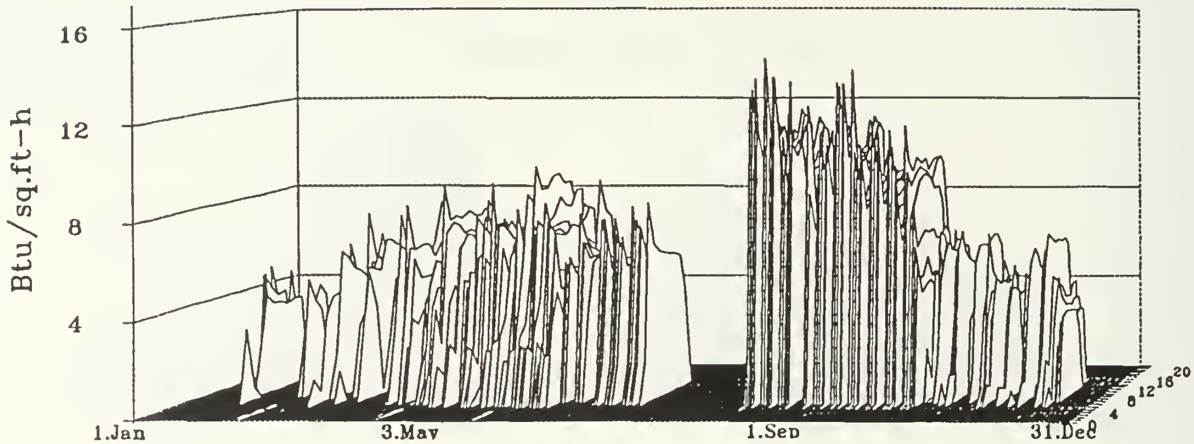




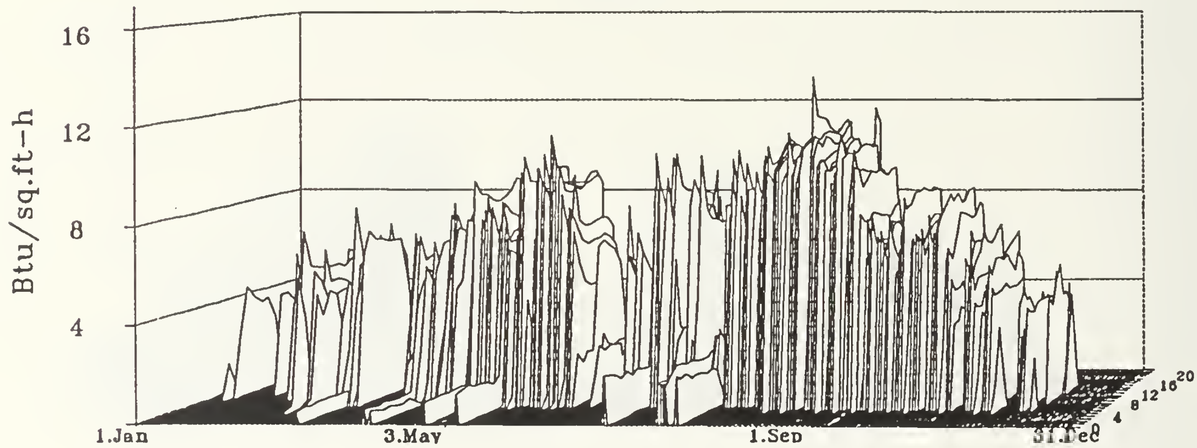


Victoria High School (VHS)
W.B. CHW as Btu/sq.ft.-h

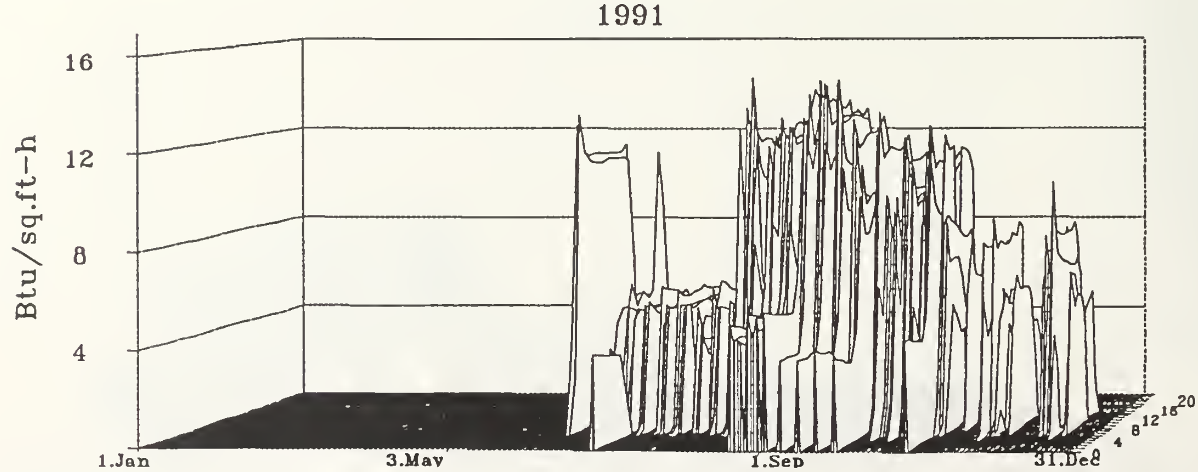
1993



1992

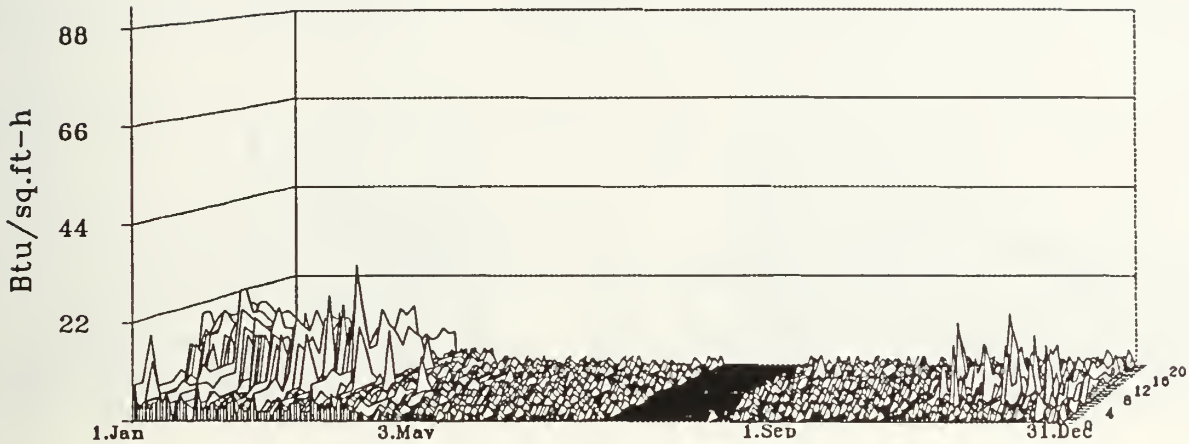


1991



Victoria High School (VHS)
W.B. HW as Btu/sq.ft.-h

1993



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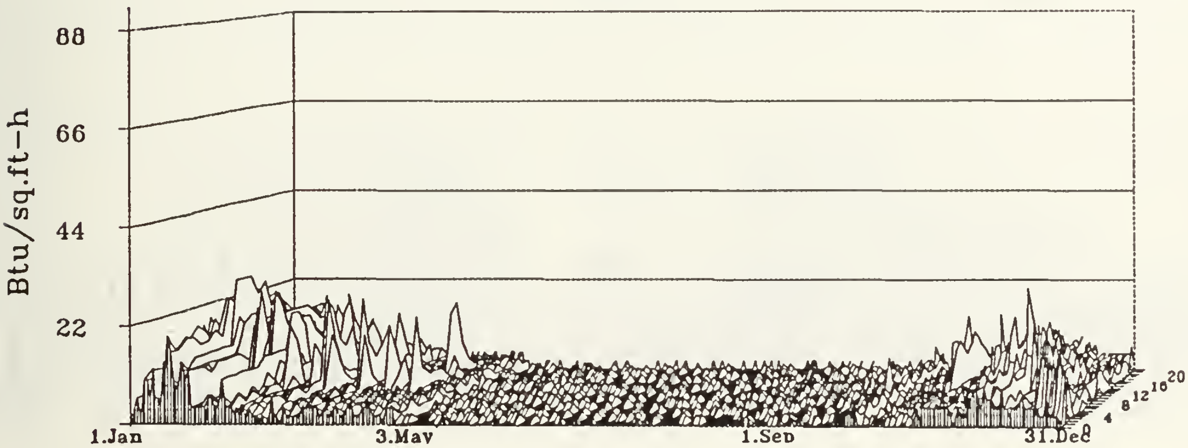
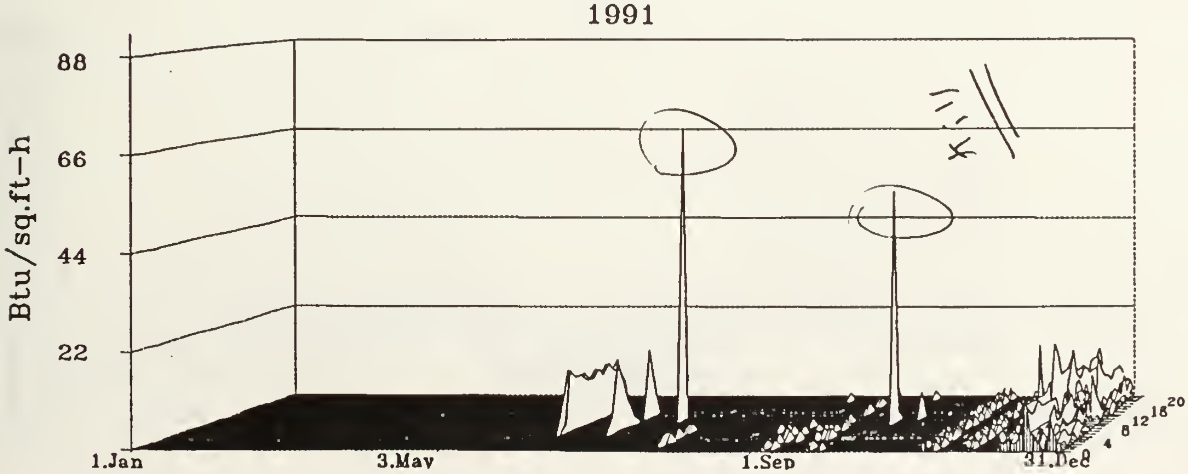
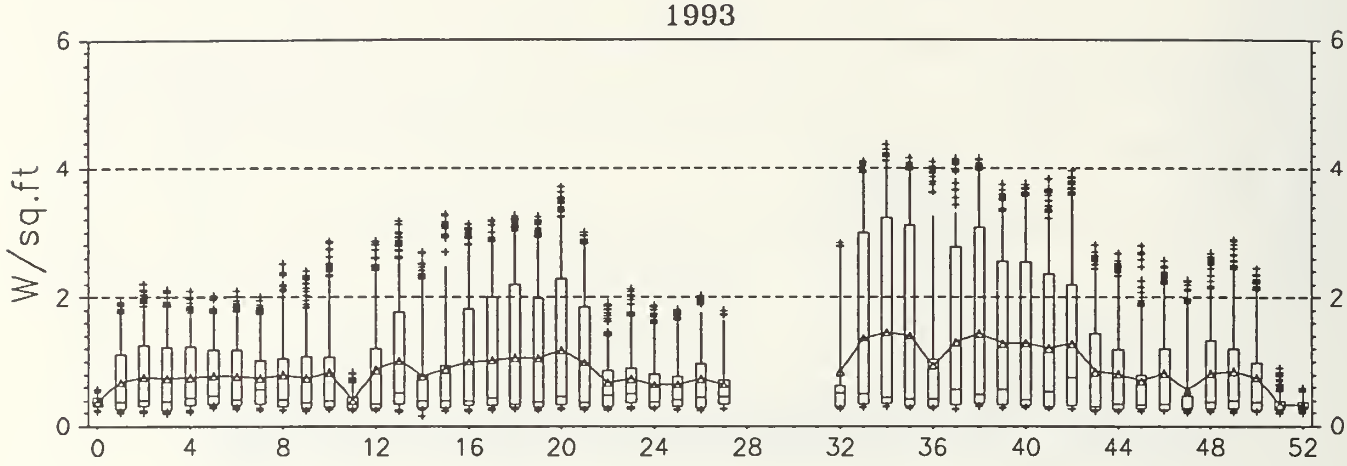
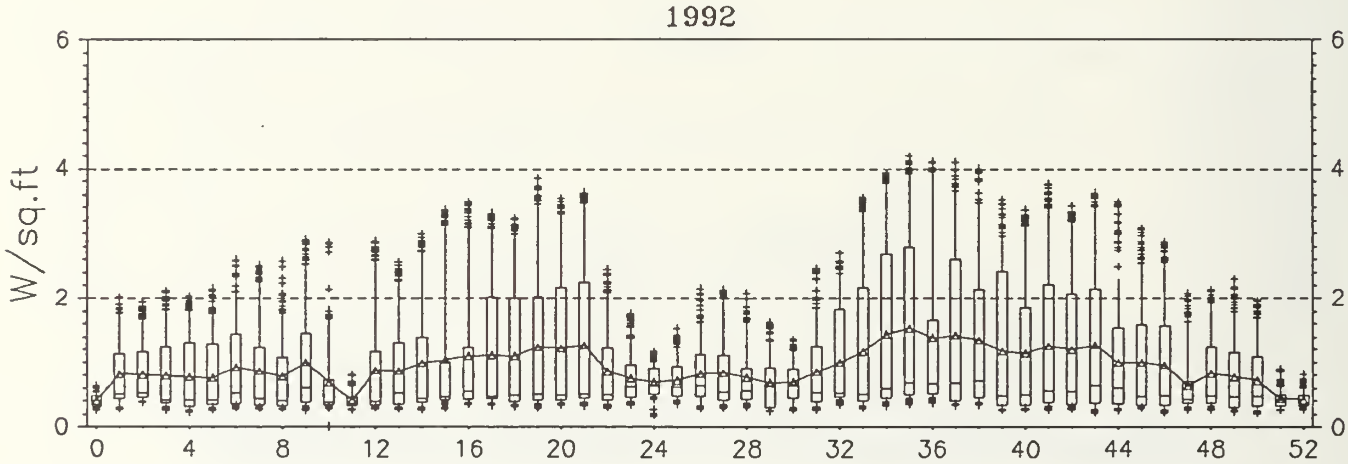


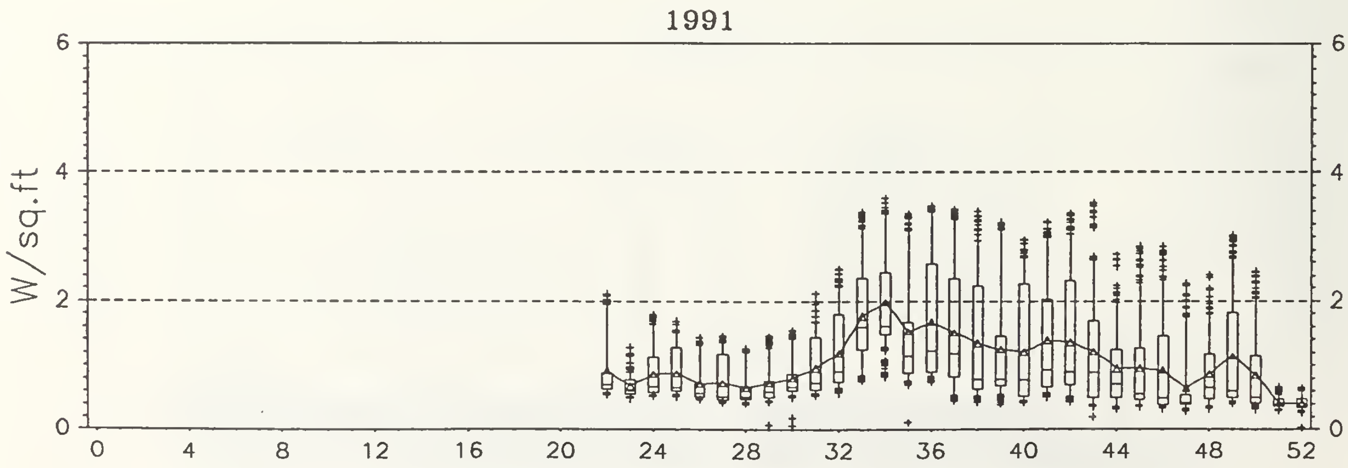
1991



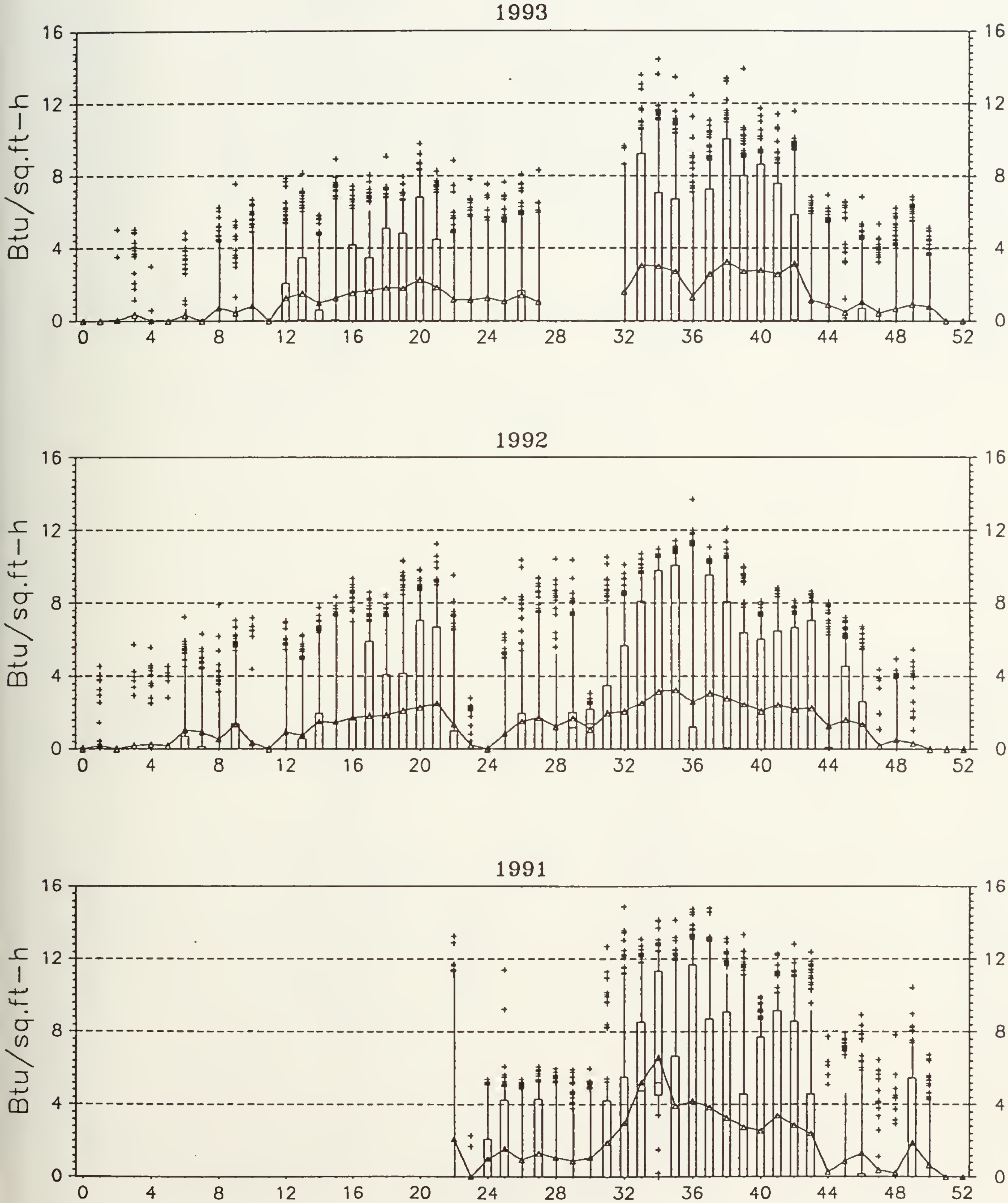
Victoria High School (VHS)
W.B. Electric as W/sq.ft.



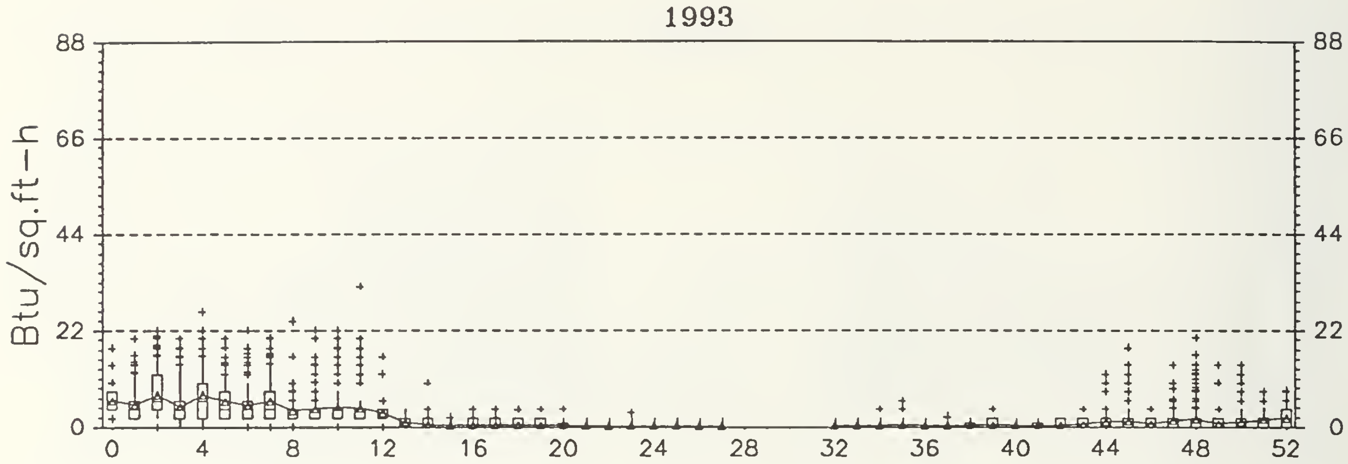


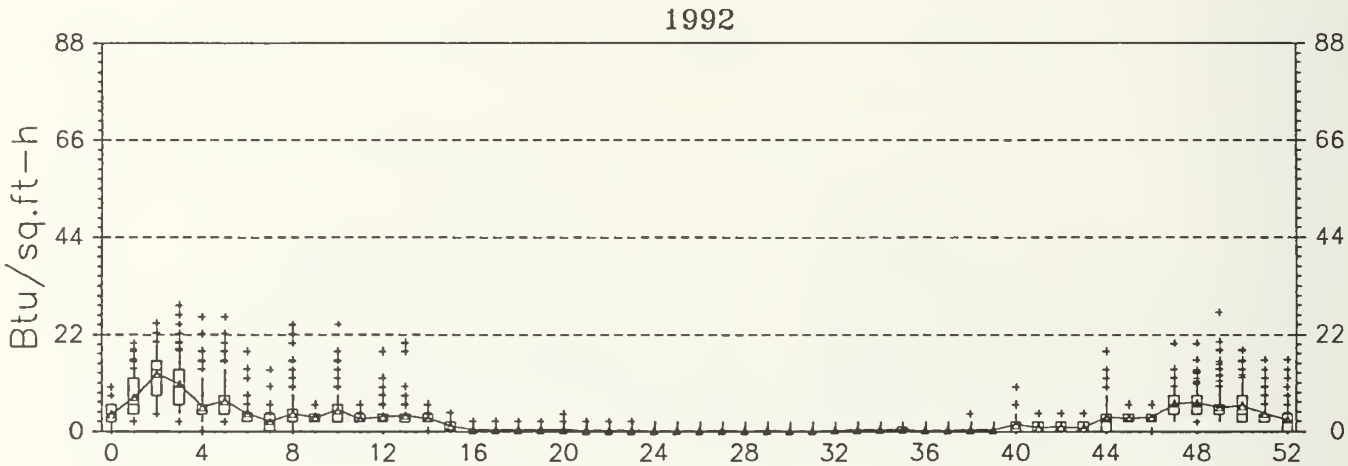


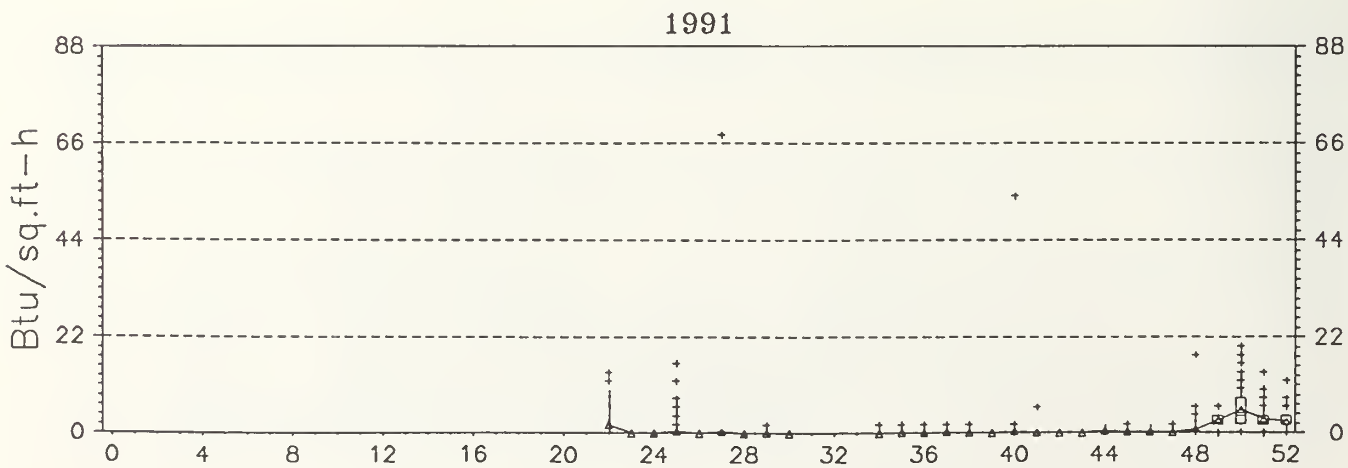
Victoria High School (VHS)
W.B. CHW as Btu/sq.ft.-h



Victoria High School (VHS)
W.B. HW as Btu/sq.ft.-h



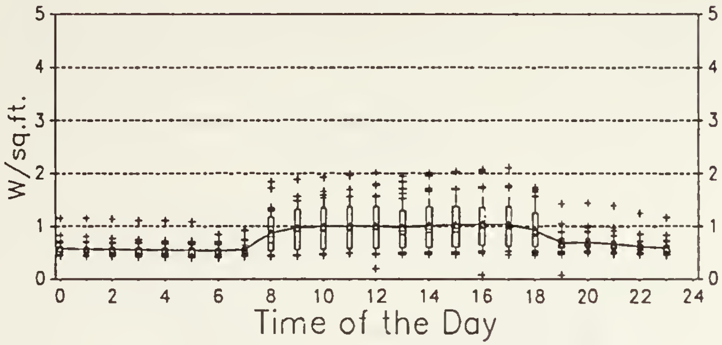




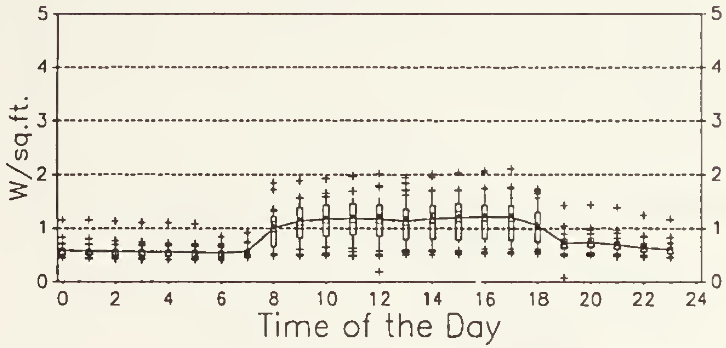
Victoria High School (VHS)
W.B. Electric as W/sq.ft.

Pre-Retrofit (06/04/1991 - 08/01/1991)

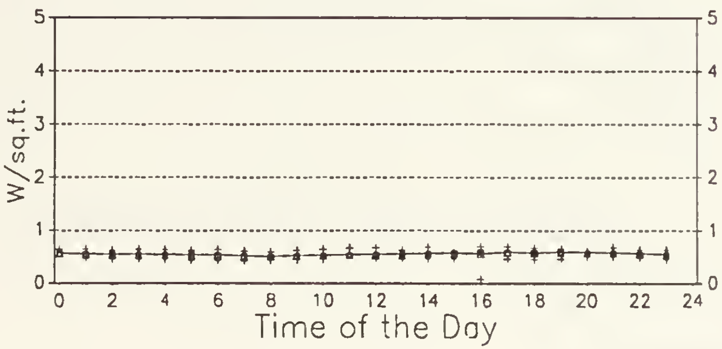
Everyday



Weekdays

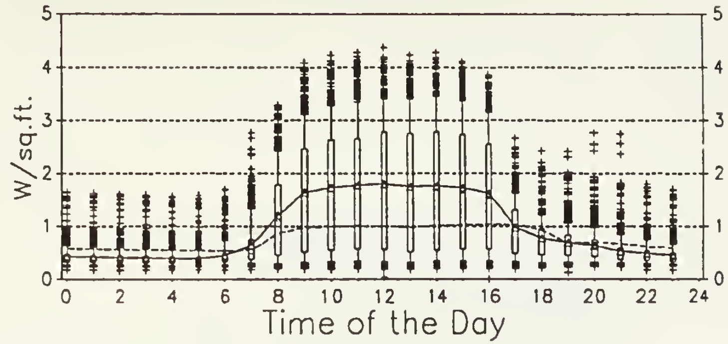


Weekends



Post-Retrofit (08/15/1991 - 12/31/1993)

Everyday



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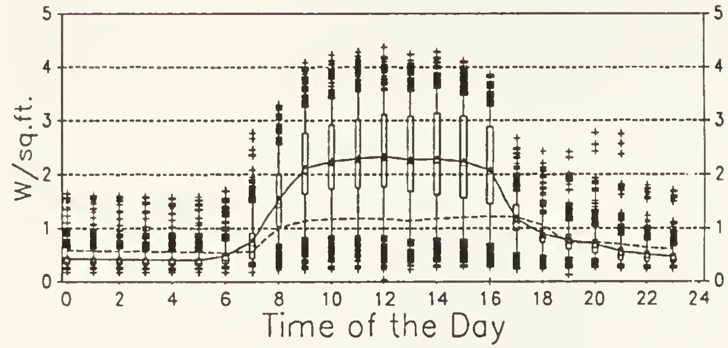
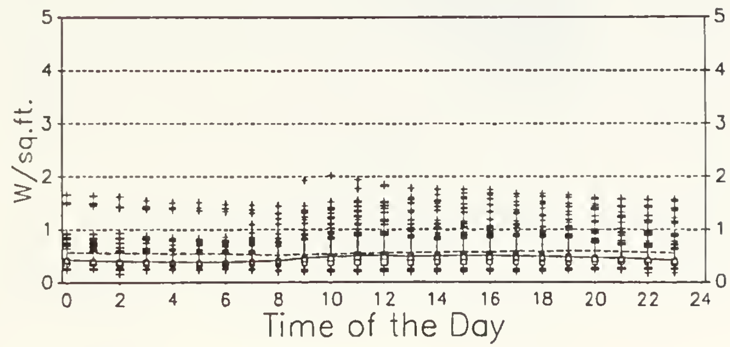


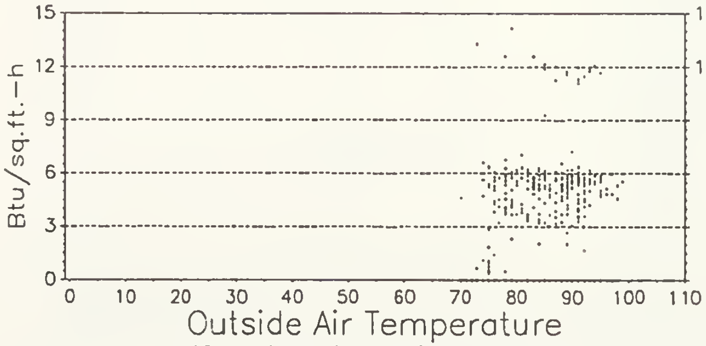
Weekends



Victoria High School (VHS)
W.B. CHW as Btu/sq.ft.-h

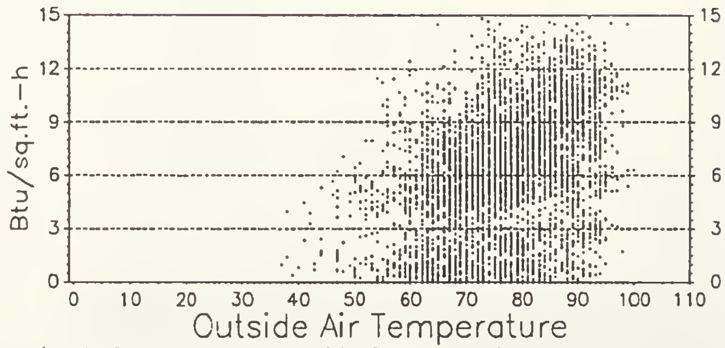
Pre-Retrofit (06/04/1991 - 08/01/1991)

Everyday



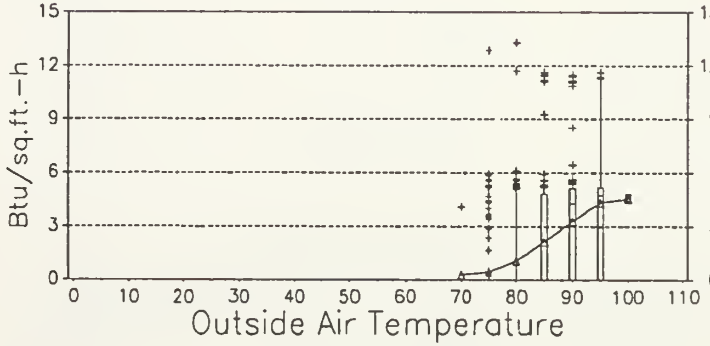
Post-Retrofit (08/15/1991 - 12/31/1993)

Everyday

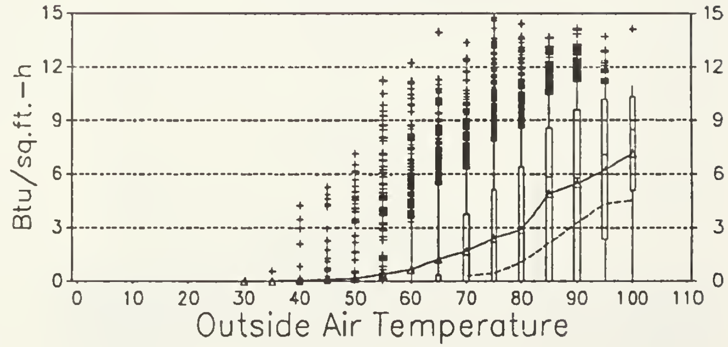


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

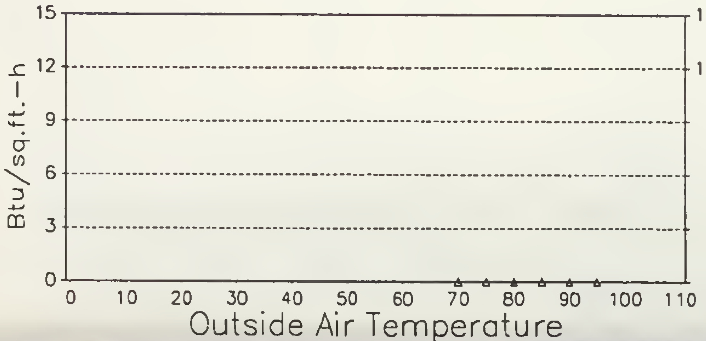
Weekdays



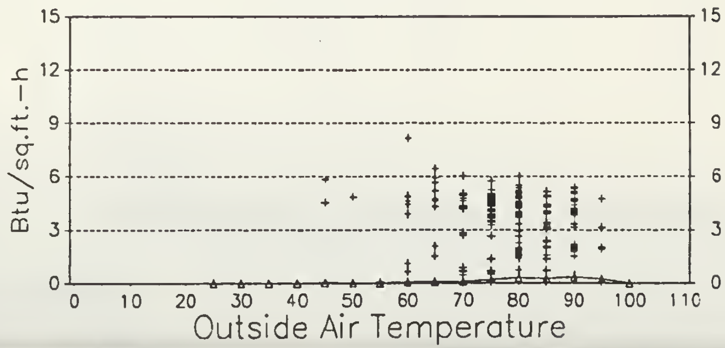
Weekdays



Weekends



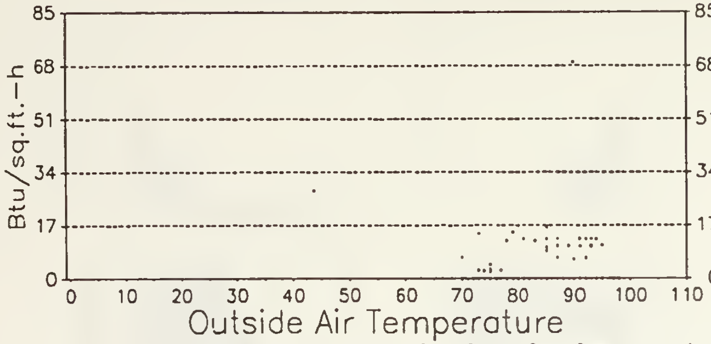
Weekends



Victoria High School (VHS)
W.B. HW as Btu/sq.ft.-h

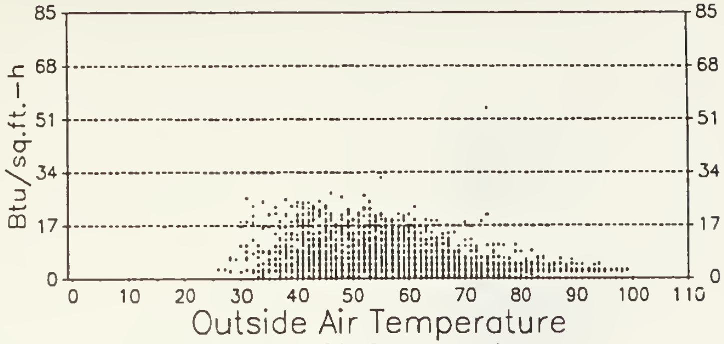
Pre-Retrofit (06/04/1991 - 08/01/1991)

Everyday



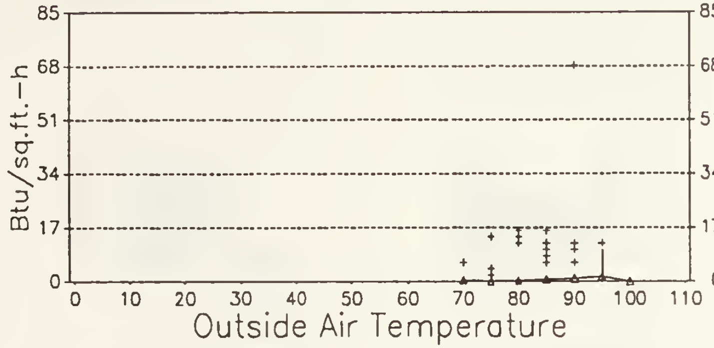
Post-Retrofit (08/15/1991 - 12/31/1993)

Everyday

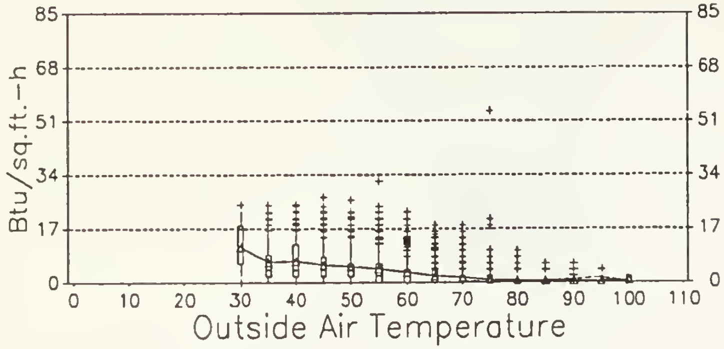


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

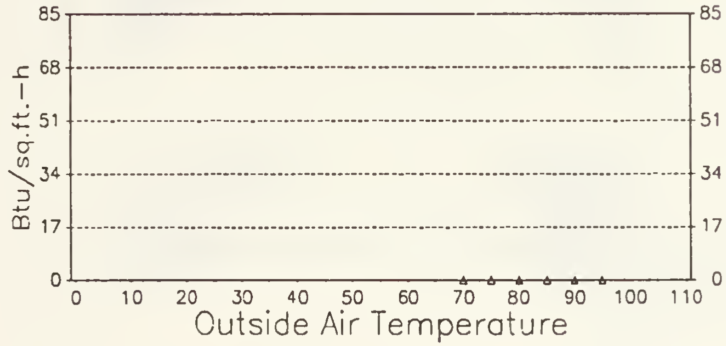
Weekdays



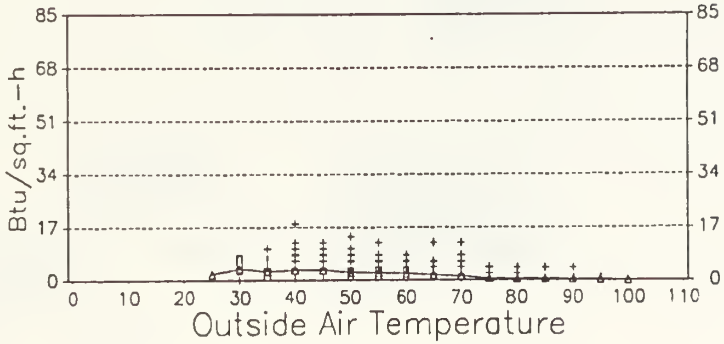
Weekdays



Weekends

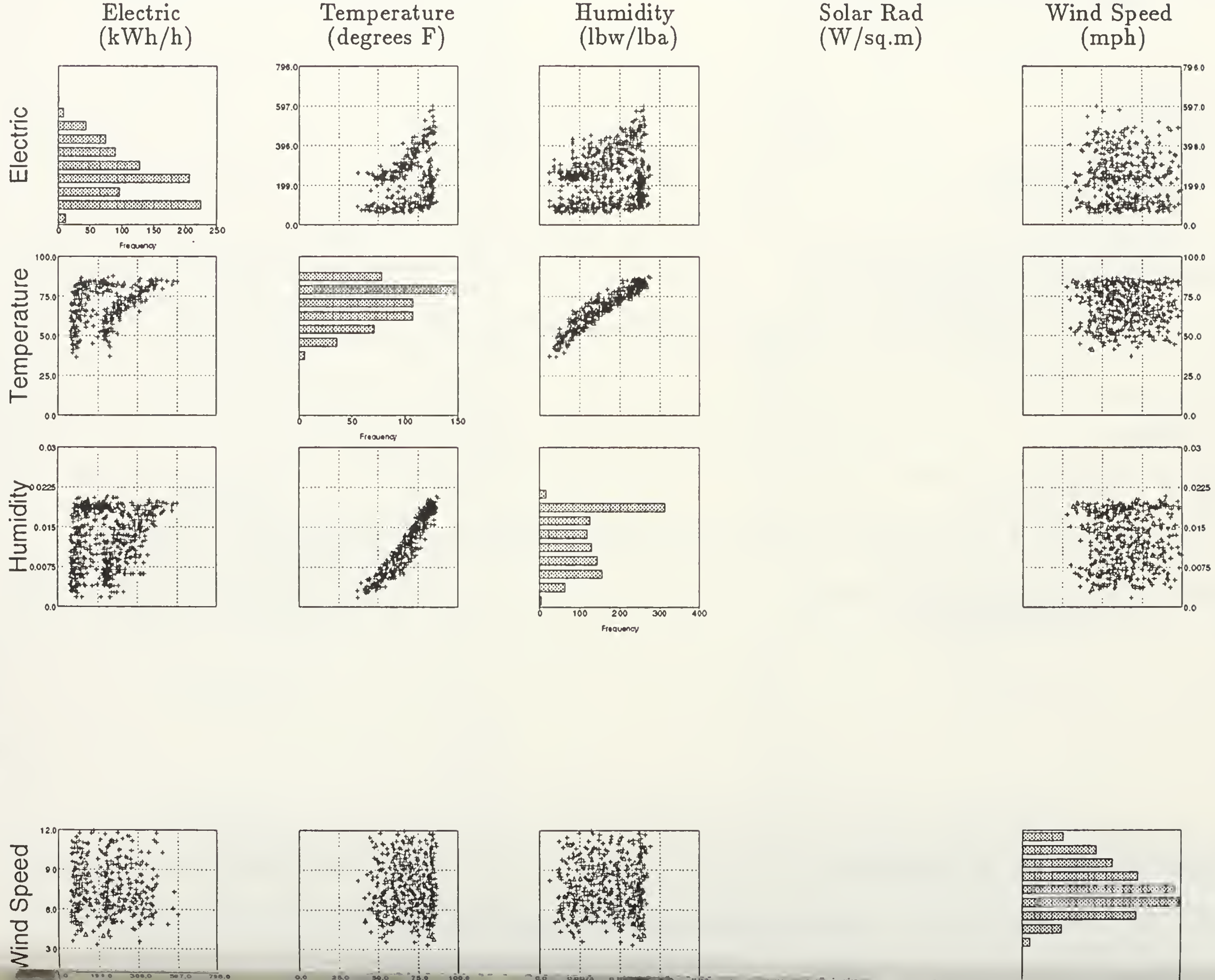


Weekends



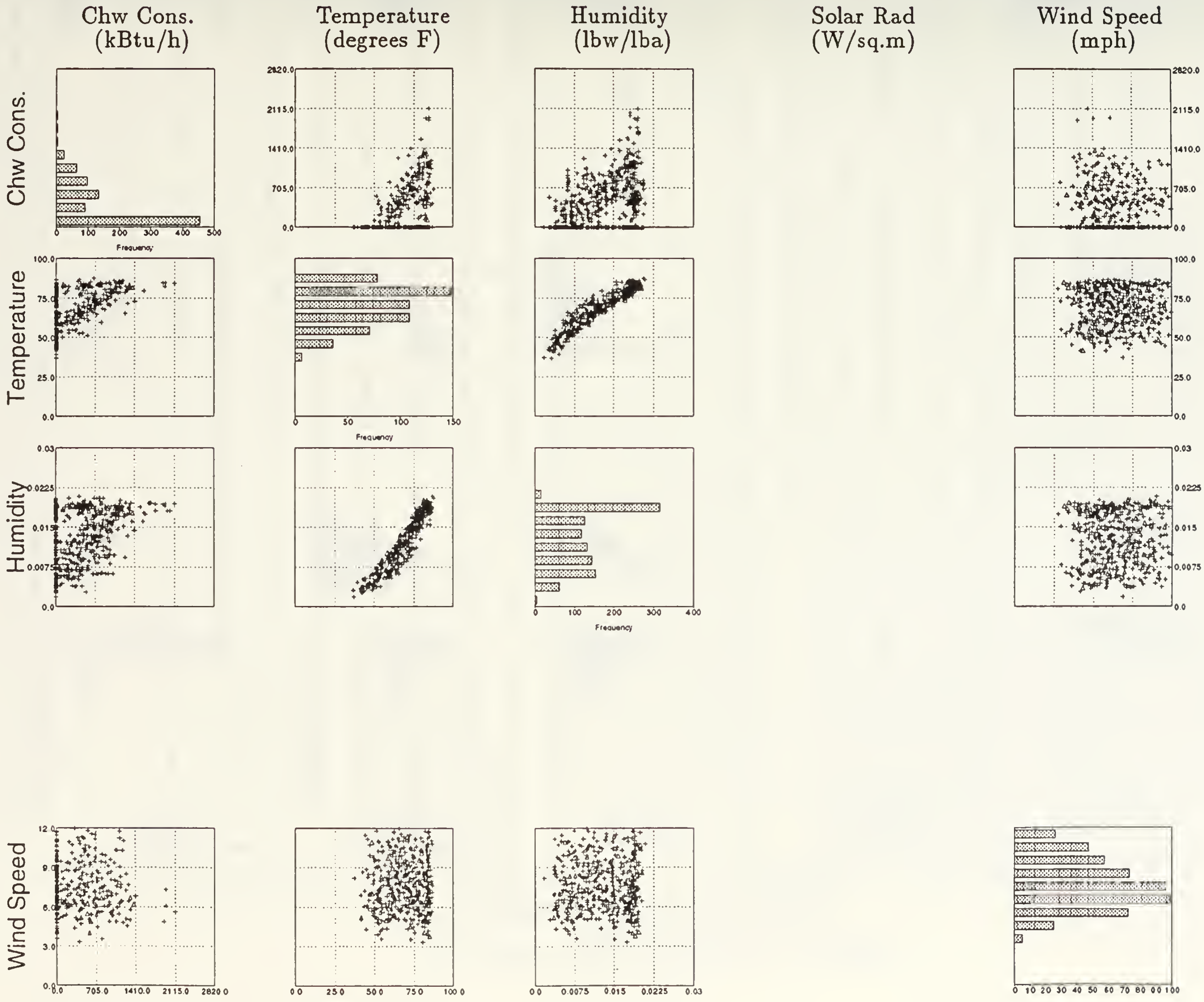
Victoria High School (VHS)
Daily Average Values

Pre-Retrofit (△) 06/04/1991 - 08/01/1991 Post-Retrofit (+) 08/15/1991 - 12/31/1993



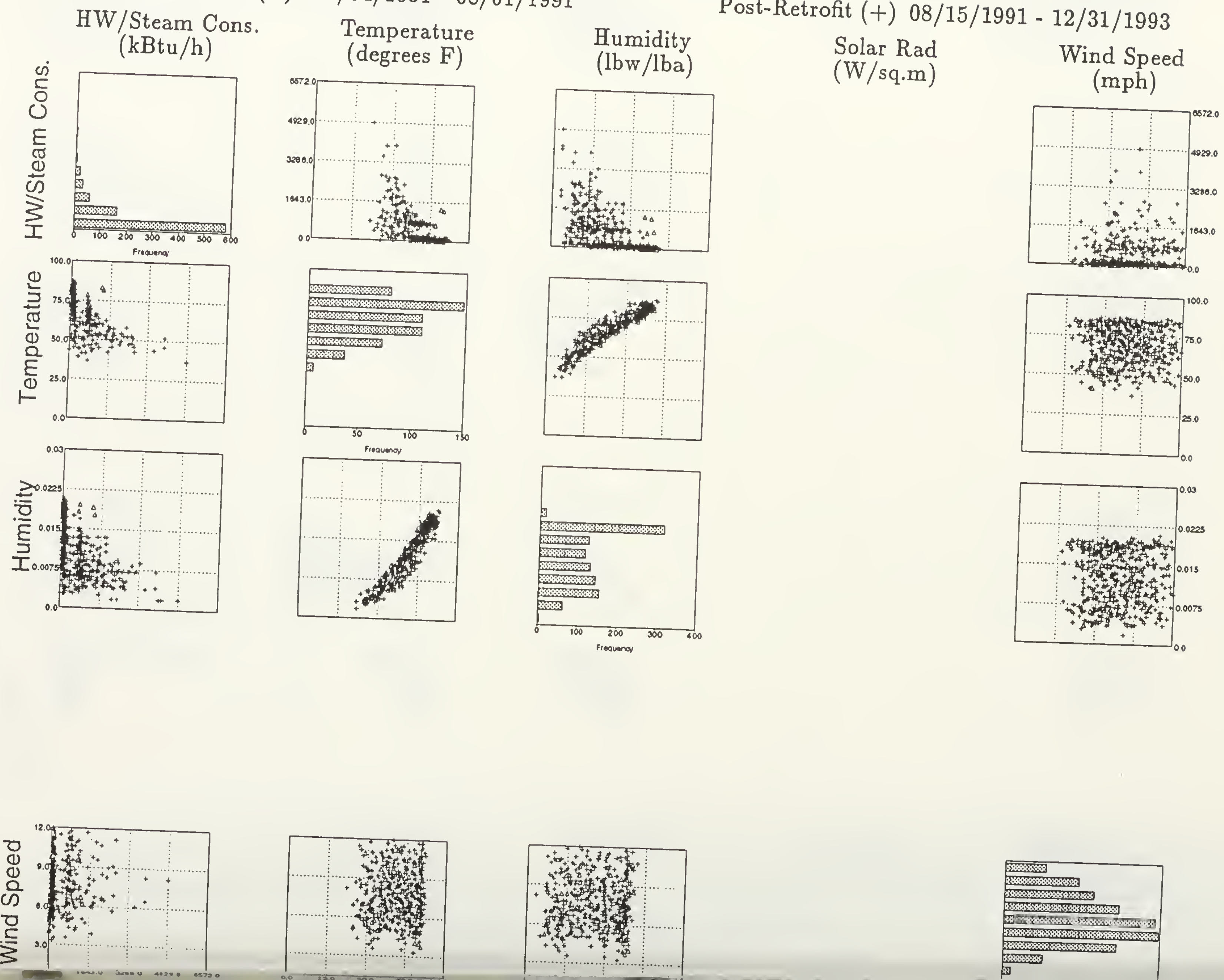
Victoria High School (VHS)
Daily Average Values

Pre-Retrofit (△) 06/04/1991 - 08/01/1991 Post-Retrofit (+) 08/15/1991 - 12/31/1993



Victoria High School (VHS)
Daily Average Values

Pre-Retrofit (△) 06/04/1991 - 08/01/1991   Post-Retrofit (+) 08/15/1991 - 12/31/1993



C. SIMS ELEMENTARY SCHOOL

C.1 Site Description[1]

Sims Elementary School is located in Fort Worth, Texas. It is a 62,400 square foot, single story, concrete building with single pane, tinted, operable windows.

The school is operated from August through May, with approximately 862 students and 50 faculty and staff. The maximum school occupancy is from about 7:00 a.m. through 3:00 p.m. The building has a lower occupancy during the weekend. There are also three summer sessions of three weeks duration each, during the morning in the summertime, with only about 10% of the students and staff present. The school district schedule is included under Tab C-1.

Electricity is purchased from Texas Utilities Electric Company, and natural gas from Lone Star Gas Company.

C.2 EMCS Retrofit

As part of monitoring done for other retrofits at this site and Dunbar Middle School, it was decided to fine tune the existing EMCS at Dunbar Middle School. This was done as an operation and maintenance (O&M) project; separate from the other retrofits. This was a success at Dunbar Middle School. Meanwhile, a private company approached the school district, proposing the installation of a new EMCS. The school district purchased and installed a new EMCS at Sims Elementary School. The new system was operable on April 14, 1991, and has a few more capabilities than the existing system. The LoanSTAR staff at Texas A&M University pointed out to the school district that their existing EMCS was able to control the majority of their equipment, and if fine tuned, would operate well for them. Based on an economic analysis, it was recommended that they fine tune their existing systems instead of buying new systems for other schools within the district.

[1] Adapted from: Landman, D.S., 1995. "Preliminary Study of Advanced Diagnostic Prescreening Methods," Energy Systems Laboratory, Mechanical Engineering Department, Texas A&M University, College Station, TX.

C.3 Analysis

C.3.1 Snapshot of consumption for September 1991 through December 1993

Figures C-1 and C-2 represent monthly average consumption and peak consumption versus min-max average (or peak) monthly temperature.[2] Min-max average monthly temperature is calculated by averaging the maximum and minimum temperature each day to obtain min-max average daily temperature. The daily temperatures are then averaged over all days in each month to obtain min-max average monthly temperature.

The data points reflecting high temperature and low consumption are indicative of non-semester consumption. If those data points are ignored, there is a general increase of consumption with temperature, indicating a temperature dependence of consumption. Additionally, the post-retrofit data points are generally lower than the pre-retrofit data points. When compared to similar plots for other Texas schools in the LoanSTAR program, this site is a high energy use school. The reader is referred to the referenced report for a more detailed discussion of these plots.

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[2] Landman, D.S., 1995. "Preliminary Study of Advanced Diagnostic Prescreening Methods," Energy Systems Laboratory, Mechanical Engineering Department, Texas A&M University, College Station, TX.

Figure C-1: *Monthly Average Consumption:* **Demand, in W/sf, versus min-max average monthly temperature, in °F, for September 1991 through December 1993 (Sims Elementary School)**

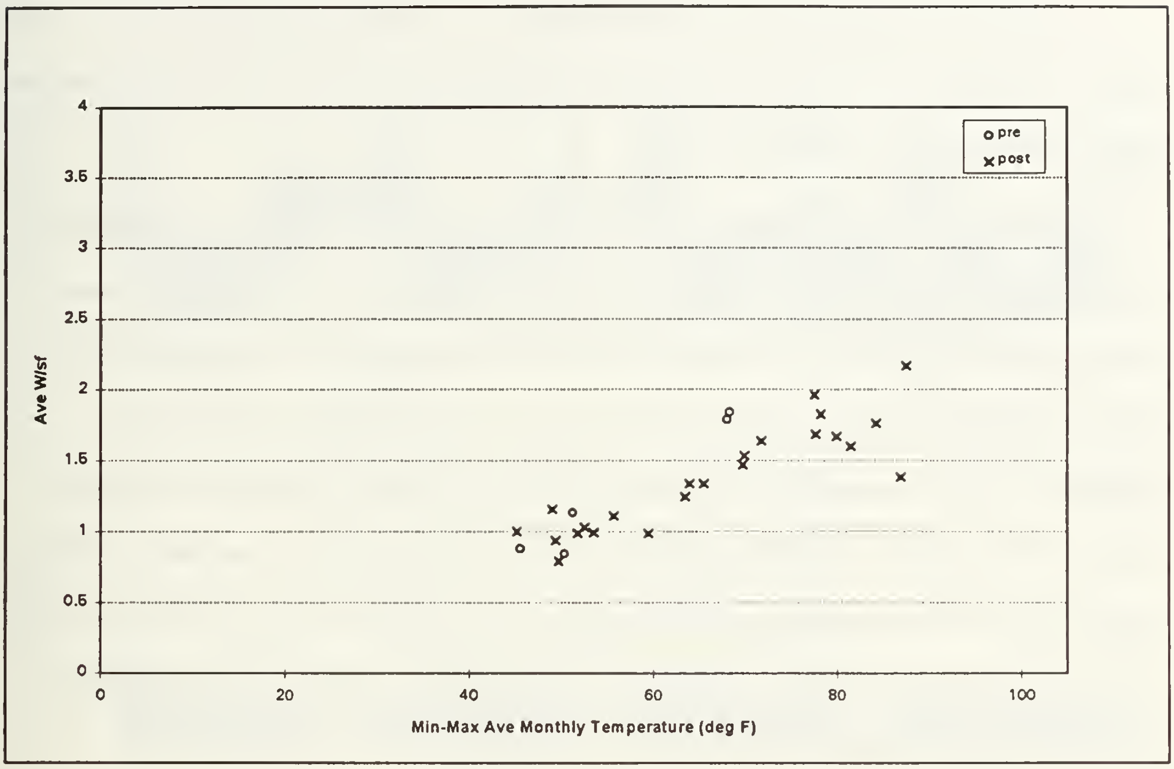
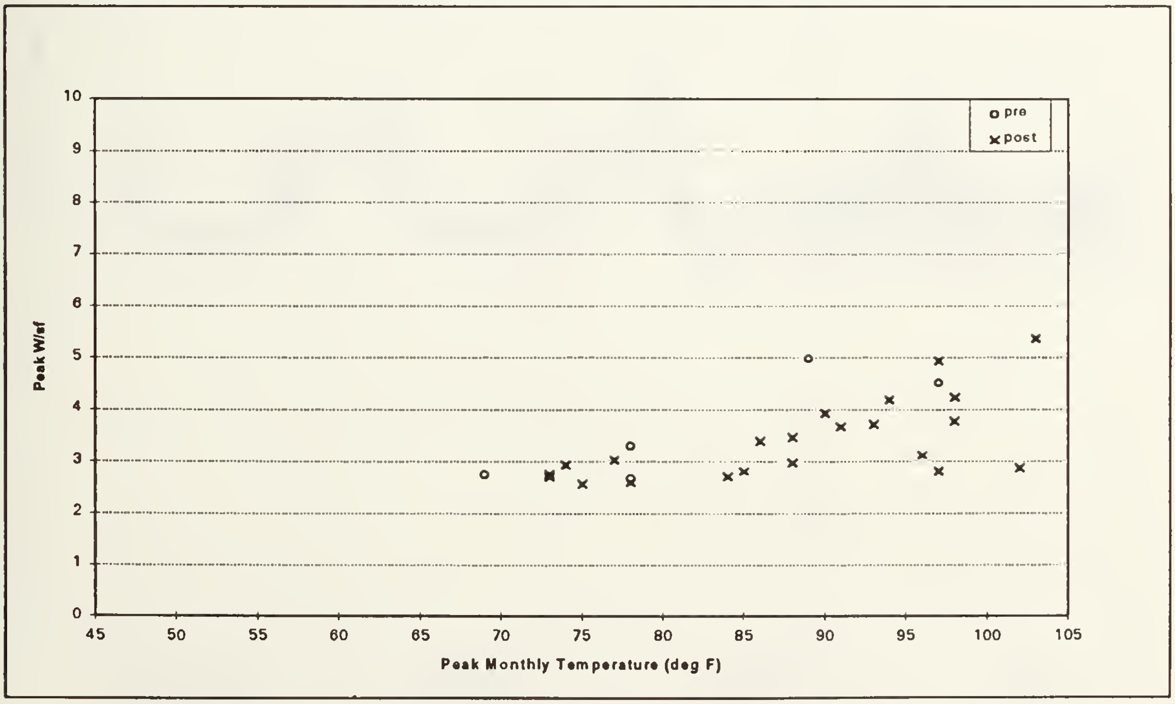


Figure C-2: *Monthly Peak Consumption:* **Demand, in W/sf, versus peak monthly temperature, in °F, for September 1991 through December 1993 (Sims Elementary School)**

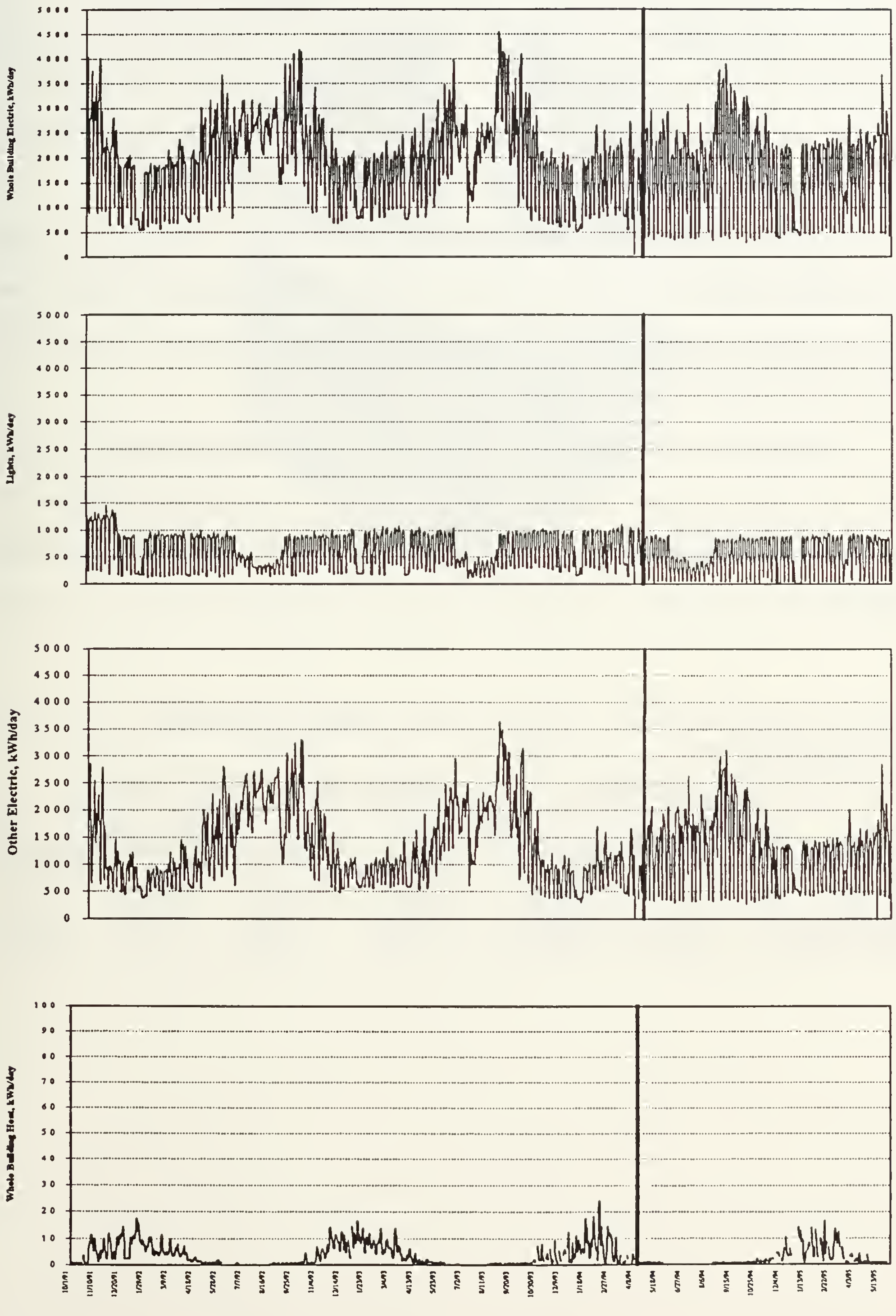


C.3.2 Timeline plots

Plots of energy consumption for the reporting period of October 1, 1991, through May 31, 1995, are shown in Figure C-3. The EMCS retrofit date of April 14, 1994, is shown by a vertical, bold line. Monitoring diagrams are provided in Tab C-2.

In looking at the whole building electric plot, there is no apparent decrease in consumption at any point along the timeline. The monitoring of electricity consumption at this site includes separate channels for whole building electric and lights. The EMCS does not control the lights, so they were subtracted from whole building electric to obtain other electric. This category consists of HVAC equipment, mostly roof top A/C units. The timeline of other electric shows a definite pattern between October 1, 1991, and April 14, 1994, the retrofit date. After the retrofit date, the consumption actually appears to increase. If the months surrounding February are analyzed for each year on the plot, one can see an increase from approximately 1,000 kWh/day to 1,500 kWh/day. The plot of whole building heat shows seasonal heating between November and April of each year.

Figure C-3: *Energy Consumption:* **time series for October 1991 to May 1995 (Sims Elementary School)**



C.3.3 Whole Building Electricity Consumption (Post-Retrofit Period)

Table C-1 shows energy consumption for the post-retrofit period (April 14, 1994, through May 31, 1995). Whole building electricity consumption is broken down into two components: lighting consumption and other electricity consumption. It is further subdivided into semester period and non-semester periods. The post-retrofit period is used because there is significantly more data available in the post-retrofit period, and it represents current usage.

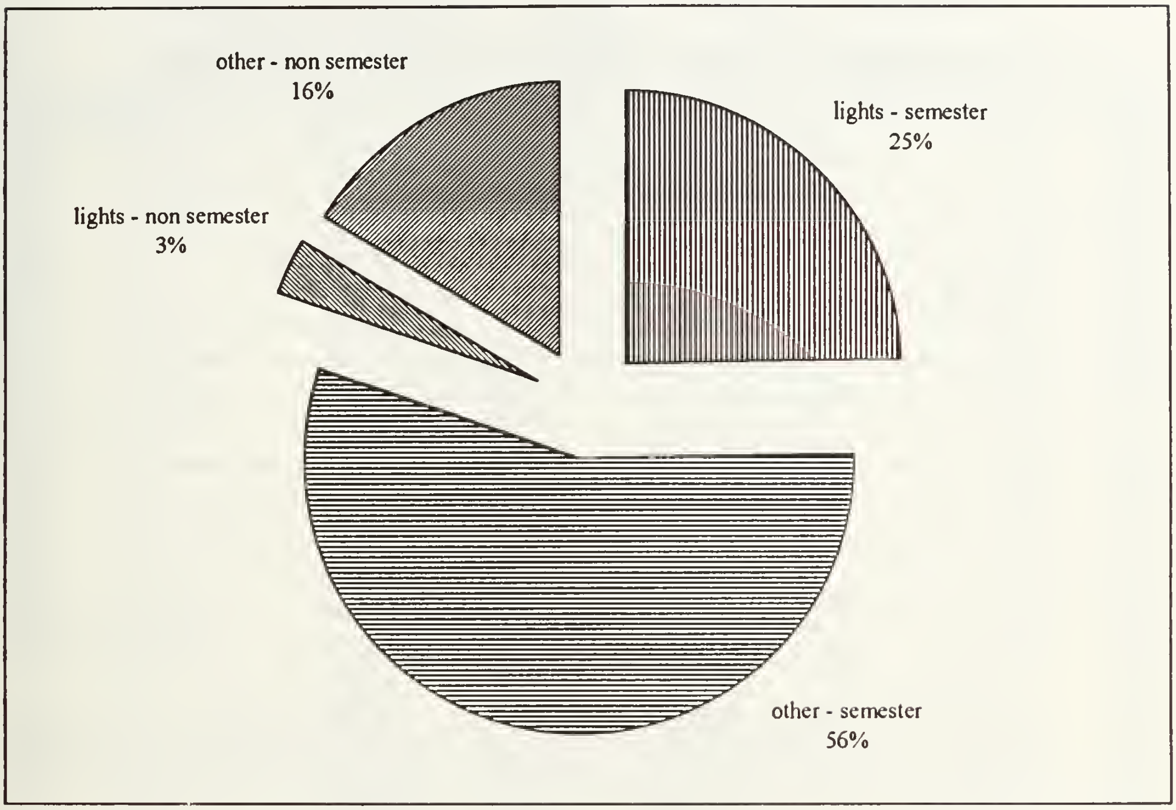
Figure C-4 graphically shows whole building electricity consumption for the post-retrofit period. For the semester period, 55% of whole building electric energy use is attributable to other electric equipment, while 26% is due to the lights. For the non-semester period, other electric accounts for 15% of whole building electric energy, while the lights account for 4%.

From both Table C-1 and Figure C-4, it is readily apparent that lighting accounts for a small portion of the whole building electricity usage. Therefore, attention for reducing energy usage should be focused on the other electricity usage. In this case, other electricity consumption is mainly roof-top HVAC units.

Table C-1: ***Energy Consumption*** **for post period, October 1991 through May 1995 (Sims Elementary School)**

	SEMESTER		NON-SEMESTER		TOTAL	
	ENERGY	$	ENERGY	$	ENERGY	$
wbelec, kWh	605,715	$40,825	142,510	$9,605	748,225	$50,430
lights, kWh	196,445	$13,240	27,258	$1,837	223,703	$15,078
other, kWh	409,270	$27,585	115,251	$7,768	524,521	$35,353
wbheat, MMBtu	588	$2,705	49	$225	637	$2,930

Figure C-4: ***Whole Building Electricity Consumption*** **for post period, April 15, 1994, through May 1995 (Sims Elementary School)**



C.3.4 Total Monthly Consumption

The total monthly energy consumption is summarized in Table C-2. Again, it is readily apparent that other electric accounts for the majority of this site's electric energy use.

Table C-2: *Monthly Energy Consumption* (Sims Elementary School)

	wbelec kWh/month	lights kWh/month	other kWh/month	wbheat MMBtu/month
PRE-RETROFIT PERIOD				
Oct 91	83,200	30,111	52,767	94
Nov	50,829	25,299	30,443	194
Dec	39,223	15,934	28,111	254
Jan 92	40,865	19,072	39,175	158
Feb	43,217	19,463	53,383	36
Mar	45,896	17,250	64,549	14
Apr	60,103	20,321	60,523	25
May	71,339	20,348	37,712	126
Jun	75,790	14,853	30,594	301
Jul	82,092	9,536	34,582	202
Aug	77,690	13,810	42,819	66
Sep	88,241	19,932	68,998	19
Oct	68,149	21,649	76,339	18
Nov	46,415	19,362	37,985	62
Dec	42,766	17,975	28,563	156
Jan 93	46,702	20,424	34,678	325
Feb	47,163	21,440	29,892	62
Mar	51,509	20,818	48,753	208
Apr	56,023	21,790	71,657	48
May	76,217	23,457	55,507	82
Jun	72,174	13,640	39,562	177
Jul	64,380	9,258	39,837	1
Aug	100,835	18,188	43,885	123
Sep	82,136	21,994	44,956	119
Oct	62,260	23,622	35,769	2
Nov	44,385	21,773	19,656	147
Dec	36,881	17,399	42,318	2
Jan 94	47,920	22,462	20,807	77
Feb	47,822	21,114	34,312	68
Mar	47,045	20,615	22,858	118
Apr (partial)	17,300	8,329	7,468	12
Total Consumption	1,816,566	591,236	1,278,455	3,294
Total Cost	$122,437	$39,849	$86,168	$15,151

**post-retrofit period and grand total shown on next page

Table C-5 (continuation): *Monthly Energy Consumption* (Sims Elementary School)

	wbelec kWh/month	lights kWh/month	other kWh/month	wbheat MMBtu/month
POST PERIOD				
Apr (partial)	32,096	11,077	6,693	13
May	55,455	18,115	12,136	12
Jun	53,858	10,086	15,211	18
Jul	49,640	8,130	14,564	33
Aug	76,882	17,289	60,594	152
Sep	69,274	18,626	53,163	215
Oct	58,523	18,894	42,543	102
Nov	47,199	16,682	55,783	20
Dec	37,715	11,858	37,564	1
Jan 95	51,821	18,954	53,586	13
Feb	48,218	17,560	17,931	10
Mar	54,202	19,076	46,095	1
Apr	52,034	18,638	37,498	46
May	61,310	18,720	18,036	2
Total Consumption	748,224	223,703	471,396	637
Total Cost	$50,430	$15,078	$31,772	$2,930

Grand Total Consumption	2,564,791	814,939	1,749,852	3,931
Grand Total Cost	$172,867	$54,927	$117,940	$18,081

C.3.5 Average Daily Consumption

Figures C-5a and C-5b depict the average daily consumption for the semester period and the non-semester period.

For the semester period (Figure C-5a) the weekday consumption greatly increased during the daytime hours (7:00 a.m. to 6:00 p.m.), and significantly decreased during the nighttime hours (6:00 p.m. to 7:00 a.m.) Although the daytime consumption increased, the profile is as expected, with the startup of an EMCS. The nighttime consumption is low, with a sharp increase to daytime levels at 7:00 a.m. At the end of the day, there is a sharp decrease in consumption, indicating that the EMCS has shut off the equipment. The reason for daytime consumption increasing has not been determined for the purposes of this report. It could be due to a number of factors, such as: installation of new equipment, repair of existing equipment that was down during the pre-retrofit period, or erroneous data.

Figure C-5a: *Semester Pre-/Post-Retrofit Comparison:* **based on average hourly data (Sims Elementary School)**

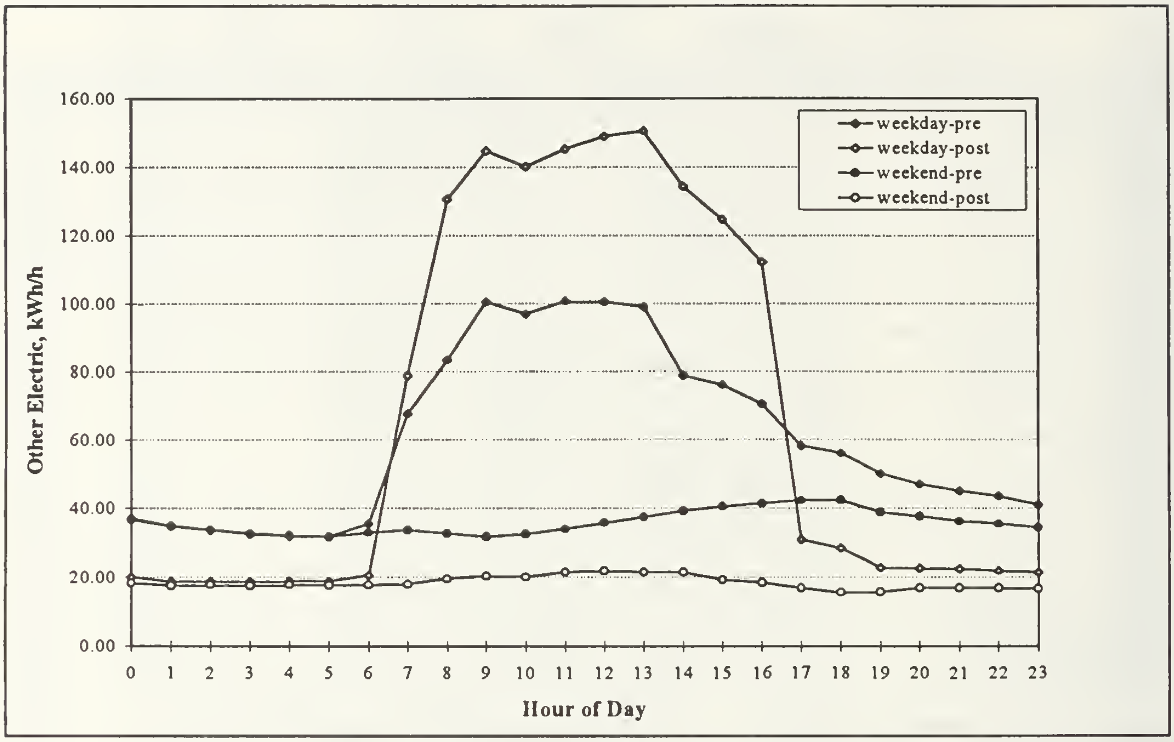
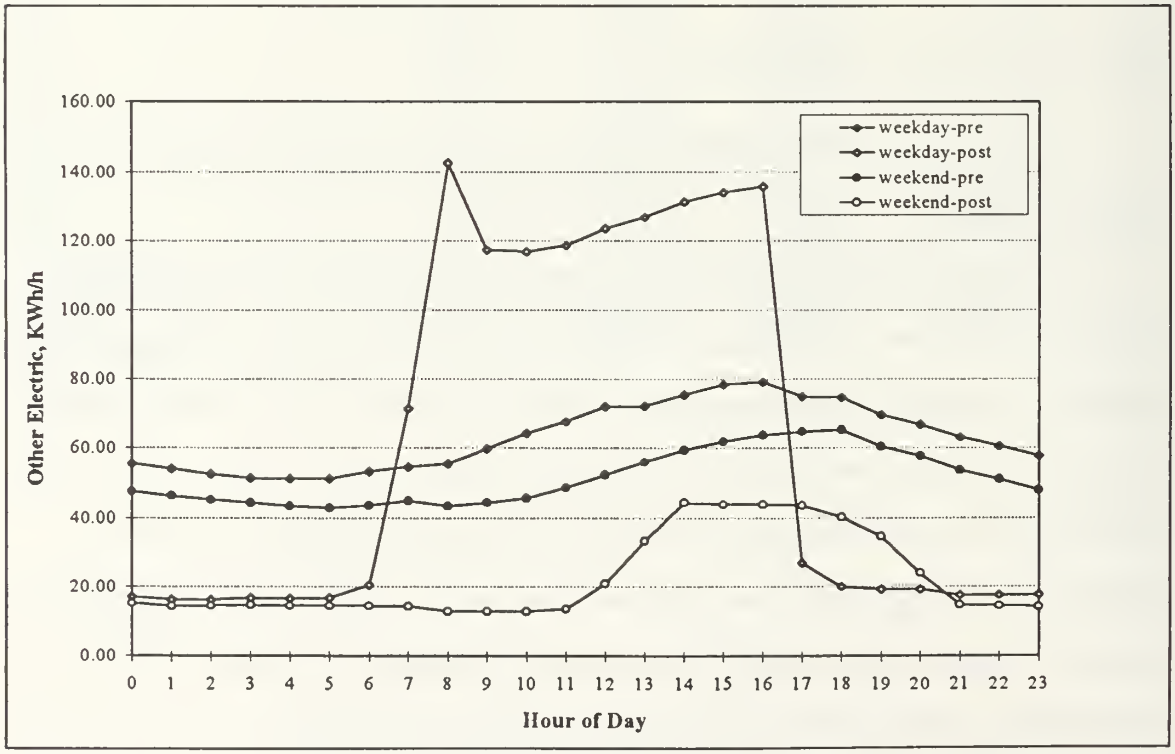


Figure C-5b: *Non-semester Pre-/Post-Retrofit Comparison:* **based on average hourly data (Sims Elementary School)**



The weekend consumption decreased over all hours between the pre-retrofit and post-retrofit periods. This is indicative of equipment being left on over the weekend during the pre-retrofit period, which is now being turned off by the EMCS.

For the non-semester period, Figure C-5b, similar results as the semester period occur. The weekday consumption dramatically decreased during the nighttime hours, but dramatically increased during the daytime hours. This may be due to the same reasons stated above in the semester period analysis. For the weekends, there was an overall decrease in consumption over all hours. The consumption increases between the hours of 12:00 p.m. and 10:00 p.m. This may be due to faculty and staff working later in the day on weekends.

Tab C-3 contains a summary of the hourly averages and the respective standard deviations and count of data points. The hourly averages are the data that is plotted in Figures C-5a and C-5b. They do not vary much for the hours of 0 through 7, then jump to higher levels in the hours of 8 through 23. This should not be alarming, because the periods that the data was averaged over include wide ranges of temperatures. As was seen earlier in Figures C-1 and C-2, the energy usage is temperature dependent. The count of data points represents the actual number of data points used to calculated the average, which corresponds to the amount of time that the equipment was actually operating.

The difference in other electric energy consumption was calculated based on the average daily data. This is shown in Table C-3, both as a difference in energy and a percentage difference in energy.

Table C-3: ***Difference in Other Electric Consumption*** **based on average daily data (Sims Elementary School)**

	# days in period	Average Daily Consumption kWh/day	Difference in Average Daily Consumption kWh/period	% Difference in Average Daily Consumption
Semester				
weekday-pre	514	1,453		
weekday-post	229	1,617	164	11.29%
weekend-pre	192	861		
weekend-post	88	444	-417	-48.41%
Non-Semester				
weekday-pre	148	1-517		
weekday-post	66	1,479	-38	-2.48%
weekend-pre	72	1,235		
weekend-post	543	-692	-692	-56.03%

C.3.6 Plots from MECR

The September MECR energy use plots for four years are shown in Tab C-4. These provide a more qualitative look at the effects of the EMCS. September 1992 is a pre-retrofit plot. Note that there is relatively high consumption between the hours of midnight to 6:00 a.m., with a gradual increase to daytime levels. This is followed by a slow decrease in consumption between the hours of 4:00 p.m. and 10:00 p.m. Most afternoon and evening consumption does not drop to nighttime levels. September 1993 is also a pre-retrofit plot, but shows slight improvement in afternoon, evening, and nighttime consumption. There is a measurable decrease in consumption in the afternoon. Although consumption between the hours of 7:00 p.m. and midnight is not as low as the hours of midnight to 6:00 a.m., there are greatly reduced when compared to September 1991. September 1994 is a post-retrofit plot. This plot displays all the telltale signs of an EMCS. The nighttime consumption is very low, with a sharp increase to daytime levels at 6:00 a.m. The consumption drops dramatically from daytime levels to nighttime levels at 4:00 p.m. There are two or three afternoons where the consumption id slightly higher than nighttime levels. This could be due to occasional special events in which certain areas of the school remain in use after hours.

It should be noted that these profiles only allow a good look at weekday data only. The weekend data is virtually unreadable from these plots. The September 1994 plots shows a typical "picket fence" pattern on the Day-of-Year axis of the top plot. This shows the weekday consumption as the peaks, and the weekend consumption as the troughs. Separating the data into weekdays and weekends, then plotting separately would enable one to better evaluate weekends, as well as weekdays.

C.3.7 Data Summary Notebook Information

The Data Summary Notebook information is included in Tab C-5. It is not analyzed in this report for this site. Since it is analyzed for Zachry Engineering Center, it is provided for informational purposes only.

Tab C-1

School District Schedules

FORT WORTH INDEPENDENT SCHOOL DISTRICT
1990-91 SCHOOL CALENDAR

people x hr/day. $/mo
people x day/month

AUGUST — 1990

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5 PAYROLL CLOSES	6	7 PAYROLL DUE	8	9	10 ALL ADM'S MEETING	11
12	13	14	15	16 NEW TEACHERS INSERVICE	17	18
19	20 ☆ CONVOCATION	21 ○	22 ○	23 ○	24 ★	25
26	27 (SCHOOL STARTS	28	29	30	31 PAYDAY	

JANUARY — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
		1 • NEW YEAR'S DAY	2 PAYROLL DUE	3	4	5
6	7	8	9	10	11) 3RD 6-WKS 29 DAYS	12
13	14 ○	15 ○	16 (	17	18	19
20	21 • M.L. KING	22 REPORT CARDS	23	24	25 PAYDAY	26
27	28	29	30	31		

MAY — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5 PAYROLL CLOSES	6	7 PAYROLL DUE	8	9	10	11
12	13	14	15	16	17	18 SHAVUOT
19 SHAVUOT	20	21	22	23	24	25
26	27 ▲ ✱ MEMORIAL DAY	28	29) 6TH 6-WKS 27 DAYS	30 ★ PAYDAY	31	

SEPTEMBER — 1990

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2 PAYROLL CLOSES	3 • LABOR DAY	4 PAYROLL DUE	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19 ROSH HASHANAH	20	21	22
23/30 PAYROLL CLOSES	24	25	26	27	28 PAYDAY YOM KIPPUR	29

FEBRUARY — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
					1 • ‡ STOCK SHOW	2
3 PAYROLL CLOSES	4	5 PAYROLL DUE	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28 PAYDAY		

JUNE — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2 PAYROLL CLOSES	3	4 PAYROLL DUE	5	6 REPORT CARDS	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23/30 PAYROLL CLOSES	24	25	26	27	28 PAYDAY	29

OCTOBER — 1990

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2 PAYROLL DUE	3	4 SUKKOT	5) 1ST 6-WKS 29 DAYS	6 STATE FAIR
7	8 (	9	10	11 SUKKOT	12	13
14	15 REPORT CARDS	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31 PAYDAY			

MARCH — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
					1) 4TH 6-WKS 31 DAYS	2
3 PAYROLL CLOSES	4 (PUBLIC SCHOOL WEEK	5 PAYROLL DUE	6	7	8	9
10	11 REPORT CARDS	12	13	14	15	16
17	18 • SPRING BREAK	19 •	20 •	21 •	22 •	23
24/31 PAYROLL CLOSES EASTER PASSOVER	25	26	27	28 PAYDAY	29 ✱ ‡ GOOD FRI SNOW DAY	30 PASSOVER

JULY — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2 PAYROLL DUE	3	4 • FOURTH OF JULY	5	6
7	8 VACATION	9	10	11	12	13
14	15 VACATION	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31 PAYDAY			

NOVEMBER — 1990

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4 PAYROLL CLOSES	5	6 PAYROLL DUE	7	8	9	10
11	12 AMERICAN EDUCATION WEEK	13	14	15	16) 2ND 6-WKS 30 DAYS	17
18	19 (	20	21 PAYDAY	22 • THANKSGIVING	23 •	24
25 PAYROLL CLOSES	26	27 PAYROLL DUE	28 REPORT CARDS	29	30	

APRIL — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2 PAYROLL DUE	3	4	5 PASSOVER	6
7	8	9	10	11	12	13
14	15	16	17	18	19) 5TH 6-WKS 29 DAYS	20
21	22 (	23	24	25	26	27
28	29 REPORT CARDS	30 PAYDAY				

AUGUST — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4 PAYROLL CLOSES	5	6 PAYROLL DUE	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30 PAYDAY	31

DECEMBER — 1990

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11 CHANUKAH	12	13	14	15
16	17	18 CHANUKAH	19 PAYDAY	20 • WINTER BREAK	21 •	22
23/30 PAYROLL CLOSES	24 • / • 31	25 • WINTER BREAK	26 •	27 •	28 •	29

○ INSERVICE/TEACHERS' PREPARATION
• HOLIDAY
☆ INSERVICE
★ TEACHERS' PREPARATION DAYS
✱ SNOW DAYS
(BEGINNING OF SIX WEEKS
) END OF SIX WEEKS
▲ MOC WORKS

1990-91 STANDARDIZED TEST DATES

SAT:
October 13, 1990
(Texas is one of nine states giving test on this date)
November 3, 1990
December 1, 1990
January 26, 1991
March 16, 1991
May 4, 1991
June 1, 1991

PSAT
October 20, 1990 - Sat.
October 23, 1990 - Tues

ACT
October 27, 1990
December 8, 1990
February 9, 1991
April 13, 1991
June 8, 1991

ITBS/TAP Grades 2, 4, 5, 6, 8, 10
April 8-19, 1991

Local Advanced Placement Examination
August 10, 1990
January 12, 1991
June 7, 1991
August 9, 1991

TAAS Grades 3, 5, 7, 9 and Exit Level

Tuesday	October 16, 1990	Writing
Wednesday	October 17, 1990	Reading
Thursday	October 18, 1990	Mathematics

TAAS Exit Level

Tuesday	April 2, 1991	Writing
Wednesday	April 3, 1991	Reading
Thursday	April 4, 1991	Mathematics

Teaching Days

1st Semester		
1st	6 weeks	29 days
2nd	6 weeks	30 days
3rd	6 weeks	29 days
Fall Semester		88 days
2nd Semester		
4th	6 weeks	31 days
5th	6 weeks	29 days
6th	6 weeks	27 days
Spring Semester		87 days

Teacher Preparation/Inservice
Aug. 20, 21, 22, 23, 24
Jan. 14, 15
May 30

Imagination Celebration
April 7-13

‡ Feb. 1 - All 12 month contract personnel will work.
✱ Snow Day or Holiday
‡ March 29 - All 12 month contract personnel will work. Holiday if not a Snow Day for students, teachers, ten month and eleven month contract personnel.
May 27 - A snow make-up day or holiday for all personnel EXCEPT 260 DAY CONTRACT.

FORT WORTH
INDEPENDENT SCHOOL DISTRICT
Quality Education For All

FORT WORTH INDEPENDENT SCHOOL DISTRICT
1991-92 SCHOOL CALENDAR

AUGUST — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4 Payroll Closes	5	6 Payroll Due	7	8	9	10
11	12	13	14	15 *	16 All ... Meeting	17
18	19 New Teachers Workshop Orientation	20	21	22	23 ★	24
25	26 (School Starts	27	28	29	30 * Payday	31

SEPTEMBER — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
1 Payroll Closes	2 • Labor Day	3 Payroll Due	4	5	6	7
8	9 Rosh Hashanah	10	11	12	13 *	14
15	16	17 Yom Kippur	18	19	20	21
22	23 Sukkot	24	25	26	27	28
29 Payroll Closes	30 * Payday Sukkot					

OCTOBER — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
		1 Sukkot Payroll Due	2	3	4) 1st 6 wks 29 days	5
6	7 (	8	9	10	11	12
13	14 Report Cards	15 *	16	17	18	19 State Fair
20	21	22	23	24	25	26
27	28	29	30	31 * Payday		

NOVEMBER — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3 Payroll Closes	4	5 Payroll Due	6	7	8	9
10	11 American Education Week	12	13	14	15 *) 2nd 6 wks 30 days	16
17	18 (	19	20	21	22	23
24	25 Report Cards	26	27 * Payday	28 Thanksgiving	29	30

DECEMBER — 1991

SUN	MON	TUE	WED	THU	FRI	SAT
1 Payroll Closes	2	3 Payroll Due Chanukah	4	5	6	7
8	9 Chanukah	10	11	12	13	14
15	16	17	18	19	20 * Payday	21
22	23 • Winter Break	24 •	25 •	26 •	27 •	28
29	30 • Winter Break	31 •				

JANUARY — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
			1 • New Year's Day	2 ▲ • Winter Break	3 ▲ •	4
5 Payroll Closes	6 Payroll Due	7	8	9	10	11
12	13	14	15 *	16) 3rd 6 wks 32 days	17 ★	18
19	20 •	21 (	22	23	24	25
26	27	28	29	30 *	31 ♦ — Stock Show	

FEBRUARY — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2 Payroll Closes	3	4 Payroll Due	5	6	7	8
9	10	11	12	13	14 *	15
16	17	18	19	20	21	22
23	24	25	26	27	28 *) 4th 6 wks 28 days Payday	29

MARCH — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
1 Payroll Closes	2 (Public School Week	3 Payroll Due	4	5	6	7
8	9 Report Cards	10	11	12	13 *	14
15	16 • Spring Break	17 •	18 •	19 •	20 •	21
22	23	24	25	26	27	28
29	30	31 * Payday				

APRIL — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5 Payroll Closes	6	7 Payroll Due	8	9	10	11
12	13	14	15 *	16) 5th 6 wks 29 days	17 ✦ Good Friday	18 Passover
19 Passover Easter	20 (	21	22	23	24	25
26	27 Report Cards	28	29	30 * Payday		

MAY — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3 Payroll Closes	4	5 Payroll Due	6	7	8	9
10	11	12	13	14	15 *	16
17	18	19	20	21	22	23
24 / 31	25 Memorial Day	26	27	28	29 * Payday	30

JUNE — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2 ○) Last Day 6th 6 wks 32 days	3 ✦ ○ Snow Day	4 ☆ ★	5	6 Payday
7 Payroll Closes	8 Payroll Due	9	10 Report Cards	11	12	13
14	15 *	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30 * Payday				

JULY — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3 • Holiday	4
5 Payroll Closes	6 Vacation	7 Payroll Due	8	9	10	11
12	13 Vacation	14	15 *	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31 * Payday	

AUGUST — 1992

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2 Payroll Closes	3	4 Payroll Due	5	6	7	8
9	10	11	12	13	14 *	15
16	17	18	19	20	21	22
23 / 30	24 * / 31	25	26	27	28	29

FORT WORTH
INDEPENDENT SCHOOL DISTRICT

Where the Future Begins...NOW!

1991-92 STANDARDIZED TESTING DATES

SAT
October 12, 1991 - Texas only
November 2, 1991
December 7, 1991
January 25, 1992
April 4, 1992
May 2, 1992
June 6, 1992

PSAT/NMSQT:
October 19, 1991 - Saturday
October 22, 1991 - Tuesday

ACT.
October 26, 1991
December 14, 1991
February 8, 1992
April 11, 1992
June 13, 1992

TAAS Norm-Referenced Testing
Grades 3, 4, 5, 6, 7, 8, 9, 10, and 11
Tuesday, April 7, 1992
Wednesday, April 8, 1992
Thursday, April 9, 1992

TAAS Criterion-Referenced Testing
Grades 3, 5, 7, 9, and Exit Level
Tues., October 8, 1991 — Writing
Wed., October 9, 1991 — Reading, TEAMS Exit Level ELA
Thur., October 10, 1991 — Mathematics, TEAMS Exit Level M

Exit Level
Tues., March 31, 1992 — Writing
Wed., April 1, 1992 — Reading, TEAMS Exit Level ELA
Thurs., April 2, 1992 — Mathematics, TEAMS Exit Level M

Local Advanced Placement Examination
August 9, 1991
January 11, 1992
May 30, 1992
August 8, 1992

C-16

SCIENCE FAIR - March 31 - April 5, 1992

• HOLIDAY
) END OF SIX WEEKS
(BEGINNING OF SIX WEEKS
▲ MOC WORKS
★ TEACHERS' PREPARATION DAYS

Teaching Days

1st Semester

1st	6 weeks	29 days
2nd	6 weeks	30 days
3rd	6 weeks	32 days
Fall Semester		91 days

2nd Semester

4th	6 weeks	28 days
5th	6 weeks	29 days
6th	6 weeks	32 days
Spring Semester		89 days

Teacher Preparation
August 23
January 17
June 4

First Student Day
August 26, 1991

History Fair
March 9-13, 1992

Social Studies Symposium
March 27-28, 1992

College Board Advanced Placement Exams
May 6-19, 1992

All-City Baccalaureate
May 24, 1992

Literacy Conference
June 22-24, 1992

— January 31 - Workday for all employees on 240 day contracts
✦ Snow Days
April 17 and June 3
* Semi-Monthly Payroll
♦ Stock Show Holiday

○ LAST DAY (if second snow day is not needed)
○ SNOW DAY ... TEACHER PREP DAY

Fort Worth Independent School District
1992-93 SCHOOL CALENDAR

AUGUST 1992

SUN	MON	TUE	WED	THUR	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23 / 30	24 / 31	25	26	27	28	29

NEW TEACHER INSERVICE

SEPTEMBER

SUN	MON	TUE	WED	THUR	FRI	SAT
		1	2	3	4	5
6	7 Labor Day	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30 Payday			

ROSH HASHANAH

OCTOBER

SUN	MON	TUE	WED	THUR	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30 Payday	31

YOM KIPPUR
SUKKOT

NOVEMBER

SUN	MON	TUE	WED	THUR	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

AMERICAN EDUCATION WEEK
THANKSGIVING

DECEMBER

SUN	MON	TUE	WED	THUR	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

WINTER BREAK

JANUARY 1993

SUN	MON	TUE	WED	THUR	FRI	SAT
					1 New Years	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24 / 31	25	26	27	28	29	30

FEBRUARY

SUN	MON	TUE	WED	THUR	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26 Payday	27
28						

MARCH

SUN	MON	TUE	WED	THUR	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

PUBLIC SCHOOL WEEK
SPRING BREAK

APRIL

SUN	MON	TUE	WED	THUR	FRI	SAT
				1	2	3
4	5 Passover	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30 Payday	

PESACH

MAY

SUN	MON	TUE	WED	THUR	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23 / 30	24 / 31	25	26	27	28	29

SHAVOUT

JUNE

SUN	MON	TUE	WED	THUR	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30 Payday			

JULY

SUN	MON	TUE	WED	THUR	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30 Payday	31

VACATION
VACATION

AUGUST 1993

SUN	MON	TUE	WED	THUR	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31 Payday				

Holiday Snow Days Teachers' Preparation Days MOC Works [Beginning of Six Weeks] End of Six Weeks
] Semi-Monthly Payroll February 5 - Workday for All Employees on 240 Day Contracts

Meetings & Events

Regular Board Meeting
2nd & 4th Tuesday of each month
Imagination Celebration Festival Week
April 1-7, 1993
PTA Council *1st Wednesday of each month*
Literacy Conference *June 22-24, 1993*
Drug Free Schools & Community Survey
Because We Care *March 3 1993*
College Night *September 23*

Teaching Days

First Semester

1st Six Weeks	*31 Days*
2nd Six Weeks	*30 Days*
3rd Six Weeks	*30 Days*
Fall Semester	*91 Days*

Second Semester

1st Six Weeks	*32 Days*
2nd Six Weeks	*25 Days*
3rd Six Weeks	*32 Days*
Spring Semester	*89 Days*

Teacher Preparation *August 21, 1992*
January 15, 1993 *June 3, 1993*
First Student Day *August 24, 1992*
Snow Days *April 9, 1993* *April 15, 1993*

Standardized Testing Dates

Scholastic Aptitude Test (SAT)
October 10,1992
November 7, 1992
December 5, 1992
January 23, 1993
March 27,1993
May 1,1993
June 5,1993

Preliminary Scholastic Aptitude Test (PSAT/NMSQT)
October 17, 1992-Saturday
October 22, 1992-Thursday

American College Testing Program (ACT)

October 24, 1992	*(Registration Deadline September 25, 1992)*
December 12, 1992	*(Registration Deadline November 13, 1992)*
February 6, 1993	*(Registration Deadline January 8, 1993)*
April 3, 1993	*(Registration Deadline March 5, 1993)*
June 12, 1993	*(Registration Deadline May 14, 1993)*

Texas Assessment of Academic Skills (TAAS)/Texas Educational Assessment of Minimum Skills (TEAMS)

September 22-24, 1992	Grades 3 and 7 (TAAS ONLY)
October 27-29, 1992	Grades 11 and 12
May 4-6, 1993	Grades 4, 8, 10, 11, 12

Norm-Referenced Assessment Program of Texas (NAPT)
April 12-16, 1993 Grades 3, 4, 5, 6, 7, 8, 9, 10, and 11

Local Advanced Placement Examination
August 8, 1992 January 16, 1993 June 12, 1993 August 7, 1993

College Board Advanced Placement Examinations
May 5-18, 1993

FORT WORTH
INDEPENDENT SCHOOL DISTRICT
Where the Future Begins ... Now

Fort Worth Independent School District
1993-94 SCHOOL CALENDAR

AUGUST 1993

SUN	MON	TUE	WED	THUR	FRI	SAT
1 Payroll Closes	2	3 Payroll Due	4	5	6	7
8	9	10	11	12	★13 Semi-Monthly Payday	14
15	16 School Starts	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31 Payday				

SEPTEMBER 1993

SUN	MON	TUE	WED	THUR	FRI	SAT
			1	2	3	4
5 Payroll Closes	6 Labor Day	7 Payroll Due	8	9	10	11
12	13	14	15 Semi-Monthly Payday	16 Rosh Hashanah	17	18
19	20	21	22	23	24	25 Yom Kippur
26	27	28	29	30 Payday		

OCTOBER 1993

SUN	MON	TUE	WED	THUR	FRI	SAT
					1	2
3 Payroll Closes	4	5 Payroll Due	6	7	8	9
10	11	12	13	14	15 Semi-Monthly Payday	16
17	18	19	20	21	22	23
24 / Payroll Closes 31	25	26	27	28	29 Payday	30

NOVEMBER 1993

SUN	MON	TUE	WED	THUR	FRI	SAT
	1	2 Payroll Due	3	4	5	6
7	8	9	10	11	12	13
14	15 Semi-Monthly Payday	16	17	18	19	20
21	22	23	24 Payday	25	26	27
28 Payroll Closes	29	30 Semi-Monthly Payday & Payroll Due				

AMERICAN EDUCATION WEEK (Nov. 15–19) · THANKSGIVING (Nov. 25–26)

DECEMBER

SUN	MON	TUE	WED	THUR	FRI	SAT
			1	2	3	4
5	6	7	8 Chanukah	9	10	11
12	13	14	15	16 Chanukah	17 Payday	18
19	20 MOC Works	21 MOC Works	22 MOC Works	23	24	25 Christmas
26	27	28	29	30	31	

WINTER BREAK (Dec. 20–24) · WINTER BREAK (Dec. 27–31)

JANUARY 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
						1 New Years
2 Payroll Closes	★3	4 Payroll Due	5	6	7	8
9	10	11	12	13	14 Semi-Monthly Payday	15
16	(17) M.L. King	18	19	20	21	22
23 / Payroll Closes 30	24 / Semi-Monthly Payday 31	25	26	27 Payday	28	29

FEBRUARY 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
		1 Payroll Due	2	3	(4) Stock Show	5
6	7	8	9	10	11	12
13	14	15 Semi-Monthly Payday	16	17	18	19
20	21	22	23	24	25 PURIM	26
27 Payroll Closes	28 Payday					

MARCH 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
		1 Payroll Due	2	3	4	5
6	7	8	9	10	11 Semi-Monthly Payday	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26 Pesach
27	28	29	30	31 Payday		

PUBLIC SCHOOL WEEK (Mar. 7–11) · SPRING BREAK (Mar. 14–18)

APRIL 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
					● 1 Good Friday	2
3 Easter Payroll Closes	● 4	5 Payroll Due	6	7	8	9
10	11	12	13	14	15 Semi-Monthly Payday	16
17	18	19	20	21	22	23
24	25	26	27	28	29 Payday	30

PESACH (Apr. 1–2)

MAY 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
1 Payroll Closes	2	3 Payroll Due	4	5	6	7
8	9	10	11	12	13 Semi-Monthly Payday	14
15	16	17	18	19	20	21
22	23	24	25 School Year Ends	★26 Teacher Preparation	27	28
29	30 Memorial Day	31 Payday				

SHAVUOT (May 16–17)

JUNE 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
			1	2	3	4
5 Payroll Closes	6	7 Payroll Due	8	9	10	12
12	13	14	15 Semi-Monthly Payday	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30 Payday		

JULY 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
					1	2
3 Payroll Closes	(4) Independence Day	5 Payroll Due	6	7	8	9
10	11	12	13	14	Semi-Monthly Payday 15	16
17	18	19	20	21	22	23
24 / Payroll Closes 31	25	26	27	28	29 Payday	30

VACATION (July 11–15) · VACATION (July 18–22)

AUGUST 1994

SUN	MON	TUE	WED	THUR	FRI	SAT
	1	2 Payroll Due	3	4	5	6
7	8	9	10	11	12	13
14	15 Semi-Monthly Payday	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31 Payday			

◯ Holiday ● Snow Days ★ Teachers' Preparation Days ✹ MOC Works

➪ February 4, April 4 - Workdays for All Employees on 240 Day Contracts

Traditional Calendar

Administrators Meeting *Tuesday, August 10, 1993*
First Day of School *Monday, August 16, 1993*
Last Day of School *Wednesday, May 25, 1994*
Teacher Preparation Days *Aug. 13, January 3, May 26*
First Semester (Total 87 Days)

1st Six Weeks	29 Days (ends 9/24)
2nd Six Weeks	30 Days (ends 11/5)
3rd Six Weeks	28 Days (ends 12/17)

Second Semester (Total 93 Days)

4th Six Weeks	32 Days (ends 2/18)
5th Six Weeks	28 Days (ends 4/8)
6th Six Weeks	33 Days (ends 5/25)

Report Card Dates

10/5/93	3/1/94
11/16/93	4/19/94
1/11/94	6/3/94 (Mailed)

Year-Round Calendar

Alice Carlson ES	J.P. Elder MS
Hubbard ES	Kirkpatrick MS
N. Hi Mount ES	Stripling MS
Versia Williams ES	Meadowbrook MS (dual)

First Day of School Monday, July 26, 1993
Last Day of School Tuesday, June 14, 1994
Teacher Preparation Days July 23, Jan. 7, June 15

1st Nine Weeks	July 26/Sept. 24	44 days
2nd Nine Weeks	Oct. 18/Dec. 17	43 Days
3rd Nine Weeks	Jan. 10/Mar. 11	43 Days
4th Nine Weeks	Apr. 4/June 14	50 Days

Report Card Dates

10/5/93	3/29/94
1/11/94	6/24/94 (Mailed)

Intersessions

9/25/93 - 10/15/93	3/14/94 - 4/1/94
1/3/94 - 1/7/94	6/15/94 - 7/1/94

Meetings & Events

Regular Board Meeting
2nd & 4th Tuesday of each month
Imagination Celebration Festival Week
April 5-10 (Tentative)
FWISD Fair *Ridgmar Mall, November 13, 1993*
PTA Council *1st Wednesday of each month*

Literacy Conference	*June 13-15, 1994*
History Fair	*March 7-12, 1994*
Because We Care	*March 2, 1994*
College Night	*September 20, 1993*
Social Studies Symposium	*April 22-23, 1994*

Other Calendar Dates

Snow Days *April 1, 1994 April 4, 1994*
Early Release Days *November 24, 1993*
December 17, 1993 March 11, 1994
MOC Non-Contract Day *November 26, 1993*

Year-Round Calendar (Special)

W.J. Turner ES First Day of School August 23, 1993 Last Day of School June 29, 1994
Intersessions 10/25/93 - 10/29/93 3/21/94 - 3/25/94 5/9/94 - 5/20/94
Teacher Preparation Days August 20, January 14, June 30

B.H. Carroll/New Lives First Day of School *Aug. 31, 1993* Last Day of School *Aug. 5, 1994*
Intersessions 10/13/93 - 10/22/93 2/16/94 - 2/25/94
4/20/94 - 4/29/94 5/13/94 - 6/24/94
Teacher Preparation Days August 30

Middle Learning Learning Center & Horizons Alternative School
First Day of School - Aug 23, 1993 Last Day of School - August 1, 1994
Intersessions 8/16/93 - 8/20/93 10/4/93 - 10/8/93 11/29/93 - 12/3/93
2/7/94 - 2/18/94 4/11/94 - 4/22/94 6/6/94 - 6/17/94
Teacher Preparation Days 8/13/93 8/20/93 8/2/94

See reverse side for list of 1993-94 Standardized Testing Dates and Professional Development Waiver Days

FORT WORTH
INDEPENDENT SCHOOL DISTRICT
Where the Future Begins... Now
Student Services Department

Tab C-2

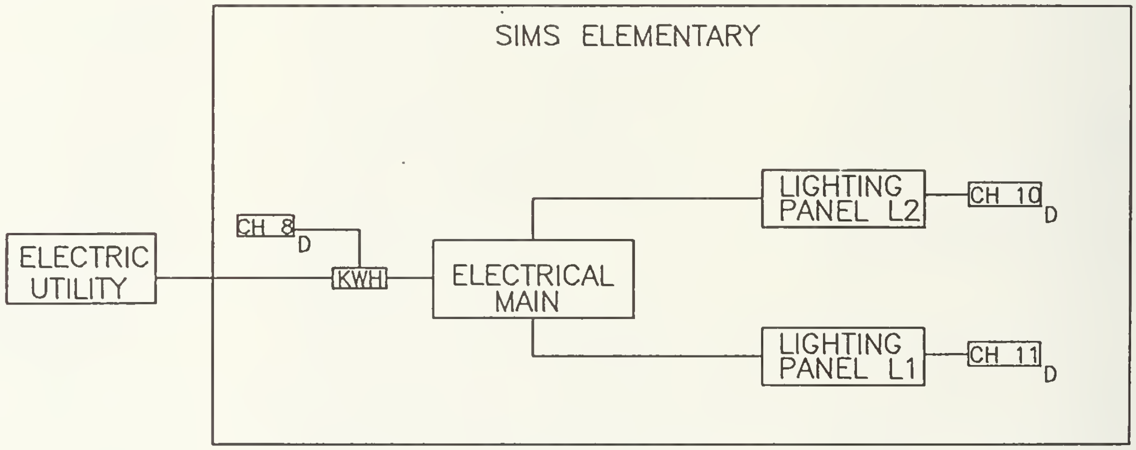
Monitoring Diagrams

ELECTRICAL MONITORING DIAGRAM

FWISD – SIMS ELEMENTARY

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL



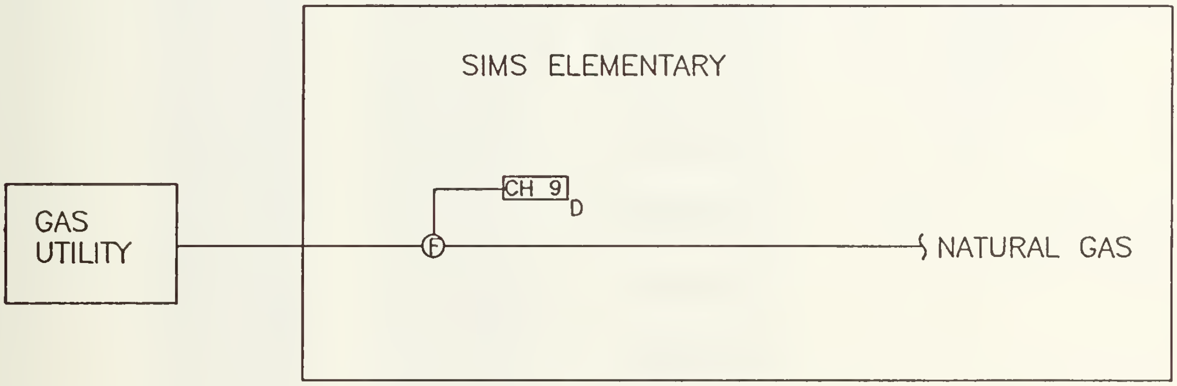
FWISD/SIMS ELEMENTARY – SITE 128

THERMAL MONITORING DIAGRAM

FWISD – SIMS ELEMENTARY

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE



FWISD/SIMS ELEMENTARY – SITE 128

Tab C-3

Average Hourly Data & Related Statistics

Hourly Average

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11
1-A-S	37.0036	34.6782	33.5772	32.5043	31.8931	31.7685	35.5423	67.5258	83.4425	100.5710	96.9066	100.8703
1-B-S	20.0102	18.7364	18.8158	18.7534	18.8949	18.8548	20.7021	78.8397	130.7057	144.7100	140.1736	145.2108
0-A-S	36.6417	34.8380	33.6766	32.6698	32.1526	31.7146	32.9667	33.6214	32.7068	31.7734	32.5677	33.8953
0-B-S	18.4023	17.6341	17.8034	17.6602	17.8761	17.7330	17.8148	18.0716	19.6420	20.4750	20.1636	21.6159
1-A-NS	55.5791	54.1007	52.5345	51.4635	51.2608	51.3932	53.3405	54.6622	55.6014	59.8851	64.3804	67.6932
1-B-NS	17.2152	16.4318	16.4712	16.9106	16.7061	16.9197	20.6152	71.4348	142.4515	117.3939	117.0091	118.6758
0-A-NS	47.4986	46.3347	45.2111	44.3153	43.4833	42.8083	43.5750	44.9514	43.5278	44.4764	45.6597	48.5861
0-B-NS	15.3167	14.4500	14.5500	14.8667	14.6167	14.5833	14.5333	14.4667	13.0000	12.9167	12.9833	13.7333

	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	100.6826	99.1445	78.8711	76.1071	70.4806	58.2544	56.0906	50.0857	46.9472	44.9806	43.6201	41.0804
1-B-S	148.9078	150.6077	134.4668	124.7947	112.3719	31.0357	28.5612	22.8565	22.6486	22.4486	22.0493	21.4389
0-A-S	35.7568	37.3995	39.0443	40.5375	41.3922	42.2656	42.3281	38.7661	37.7224	36.2891	35.4797	34.4073
0-B-S	21.8750	21.5739	21.5398	19.2636	18.4591	16.9886	15.7375	15.9205	16.9420	16.9659	16.9830	16.8375
1-A-NS	72.0736	72.2703	75.4169	78.4500	79.0831	74.8385	74.5493	69.6696	66.8527	63.2270	60.6041	57.9047
1-B-NS	123.6848	126.9273	131.2909	134.1773	135.8288	26.8879	20.1788	19.2803	19.3894	17.7742	17.7152	17.8803
0-A-NS	52.4250	56.0236	59.5708	61.9347	63.8139	64.8264	65.3097	60.4861	57.8750	53.6306	51.0958	47.9958
0-B-NS	21.0000	33.3333	44.4167	43.9167	43.9667	43.7167	40.3333	34.6167	24.1167	14.9167	14.6000	14.3167

Standard Deviation of the Hourly Average

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11
1-A-S	19.9990	18.2734	17.1404	15.9362	15.2392	14.7920	22.1803	26.8747	28.6124	35.7241	38.7061	39.2554
1-B-S	3.8050	3.6130	3.7557	3.7925	3.8605	4.3225	6.8660	41.2560	47.3032	49.8258	49.3742	51.4970
0-A-S	19.5435	17.8464	16.9142	15.5978	14.7928	14.3711	18.7134	21.4453	19.6484	19.6792	20.8988	22.1807
0-B-S	4.3559	4.1117	4.0953	4.1590	4.3359	4.2513	4.2423	5.7722	11.5400	14.2388	14.1773	19.4363
1-A-NS	32.0022	30.4493	29.0301	27.9213	27.0277	26.5548	28.0308	29.9100	31.7639	35.5873	38.6963	41.9961
1-B-NS	3.3931	3.5976	3.7856	3.7244	3.9595	3.8705	6.1481	36.8472	68.5668	53.1475	53.5467	55.5704
0-A-NS	30.3086	29.2844	27.6751	26.7747	25.7030	24.7564	25.6553	28.0513	26.6427	28.6085	30.8081	33.8070
0-B-NS	1.1405	0.5047	0.5143	0.4146	0.4734	0.6669	0.4394	3.0976	38.8305	37.6752	36.6123	38.7395

	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	41.8580	43.3770	46.8005	48.2200	47.2362	41.2426	39.6589	30.5220	28.0553	25.4724	24.1189	22.3496
1-B-S	51.9090	55.4547	54.3160	54.0045	49.4474	8.2090	6.6093	6.7973	4.7903	5.0042	4.6938	3.9888
0-A-S	24.2556	26.5095	28.1421	30.0331	31.2929	31.9350	32.1834	24.0701	23.2322	21.0007	19.8207	18.8588
0-B-S	20.3196	20.1319	21.0800	14.1179	13.7331	8.0694	3.5504	3.6415	3.7757	3.7913	3.9263	4.6412
1-A-NS	44.8028	44.8824	47.0708	49.3619	50.4176	48.9894	48.7986	44.1216	42.0862	39.1198	36.5888	34.1911
1-B-NS	57.5960	59.7648	63.3602	65.4916	65.7607	19.6708	15.6298	13.3994	9.9383	2.8138	2.9118	3.1374
0-A-NS	37.3635	40.4356	44.8073	46.7191	48.6499	50.5620	49.9563	44.3308	41.9048	37.4643	34.9103	31.2156
0-B-NS	42.6092	51.1209	56.8231	54.3267	48.0413	46.0473	43.2791	41.0516	19.6968	0.9521	0.4740	0.5519

Count of Data Points

	Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11
1-A-S	514	514	514	514	514	514	514	514	514	514	514	514
1-B-S	229	229	229	229	229	229	229	229	229	229	229	229
0-A-S	192	192	192	192	192	192	192	192	192	192	192	192
0-B-S	88	88	88	88	88	88	88	88	88	88	88	88
1-A-NS	148	148	148	148	148	148	148	148	148	148	148	148
1-B-NS	66	66	66	66	66	66	66	66	66	66	66	66
0-A-NS	72	72	72	72	72	72	72	72	72	72	72	72
0-B-NS	38	38	38	38	38	38	38	38	38	38	38	38

	Hour 12	Hour 13	Hour 14	Hour 15	Hour 16	Hour 17	Hour 18	Hour 19	Hour 20	Hour 21	Hour 22	Hour 23
1-A-S	514	514	514	514	514	514	514	514	514	514	514	514
1-B-S	229	229	229	229	229	229	229	229	229	229	229	229
0-A-S	192	192	192	192	192	192	192	192	192	192	192	192
0-B-S	88	88	88	88	88	88	88	88	88	88	88	88
1-A-NS	148	148	148	148	148	148	148	148	148	148	148	148
1-B-NS	66	66	66	66	66	66	66	66	66	66	66	66
0-A-NS	72	72	72	72	72	72	72	72	72	72	72	72
0-B-NS	38	38	38	38	38	38	38	38	38	38	38	38

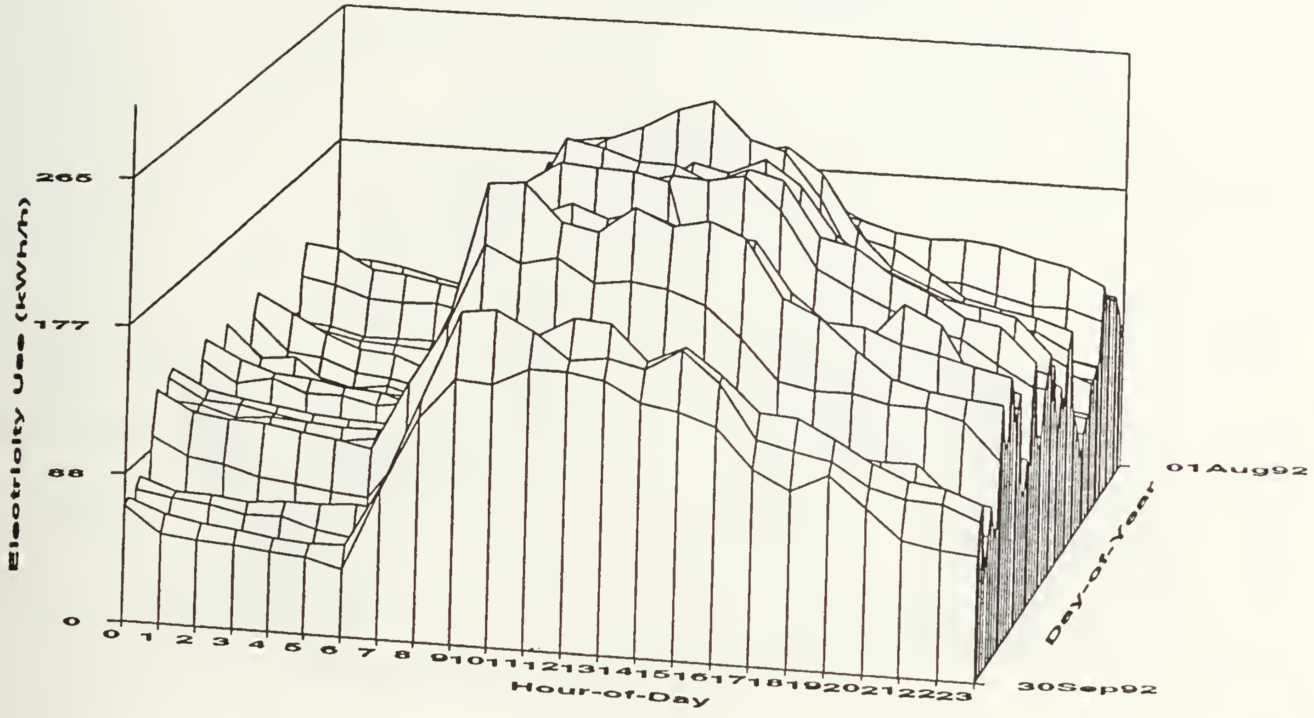
Key

1-A-S	=	Semester/Weekday/Pre-Retrofit
1-B-S	=	Semester/Weekday/Post-Retrofit
0-A-S	=	Semester/Weekend/Pre-Retrofit
0-B-S	=	Semester/Weekend/Post-Retrofit
1-A-NS	=	Non-Semester/Weekday/Pre-Retrofit
1-B-NS	=	Non-Semester/Weekday/Post-Retrofit
0-A-NS	=	Non-Semester/Weekend/Pre-Retrofit
0-B-NS	=	Non-Semester/Weekend/Post-Retrofit

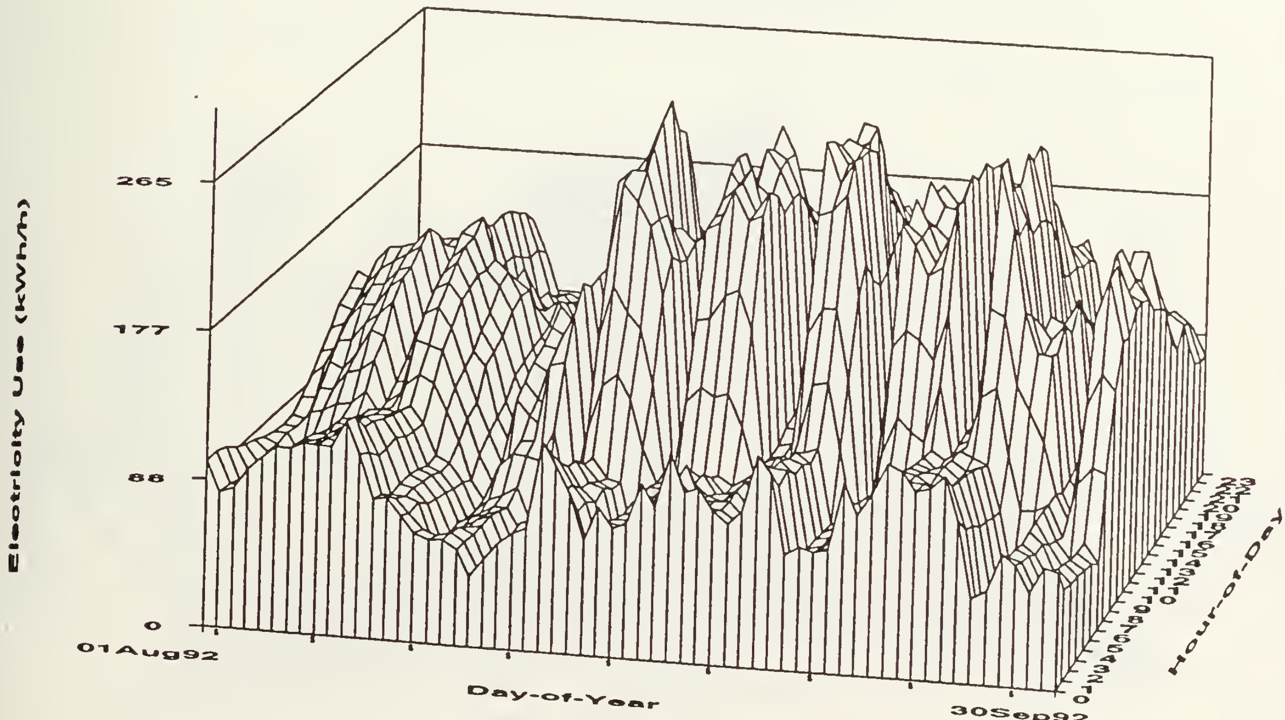
Tab C-4

MECR Plots

Whole-Building Electric



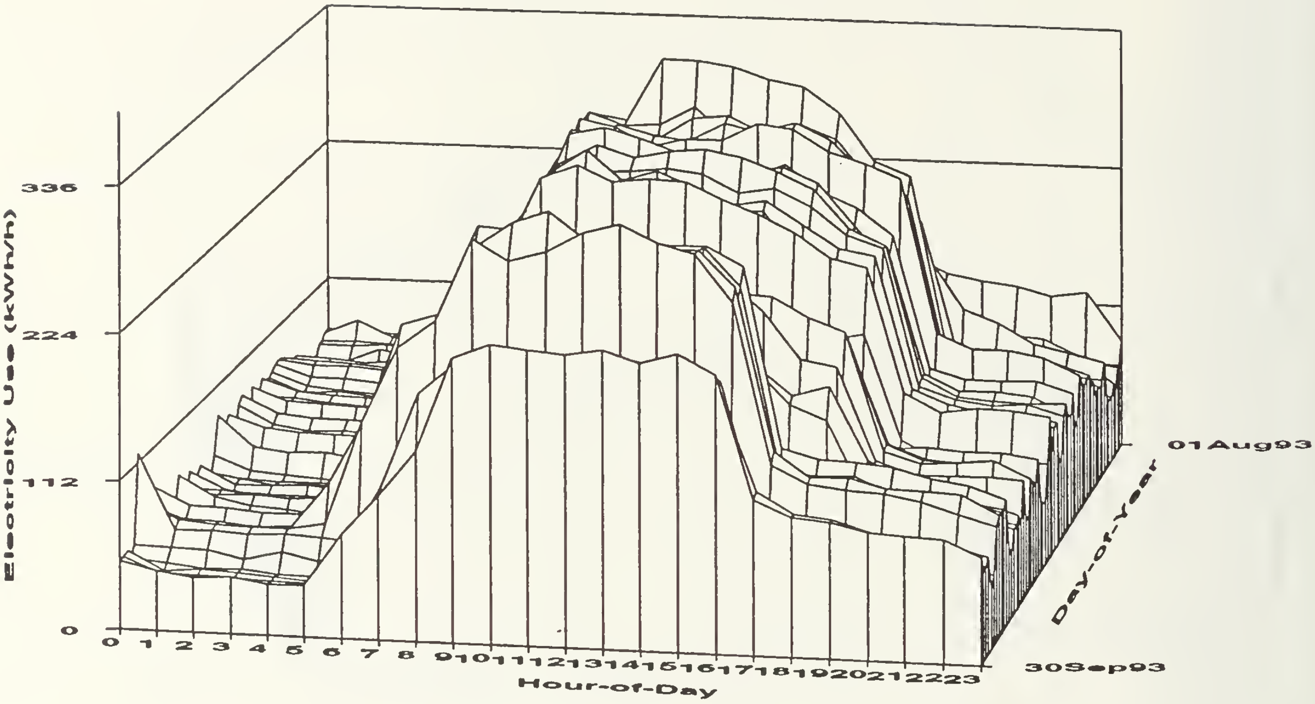
Whole-Building Electric



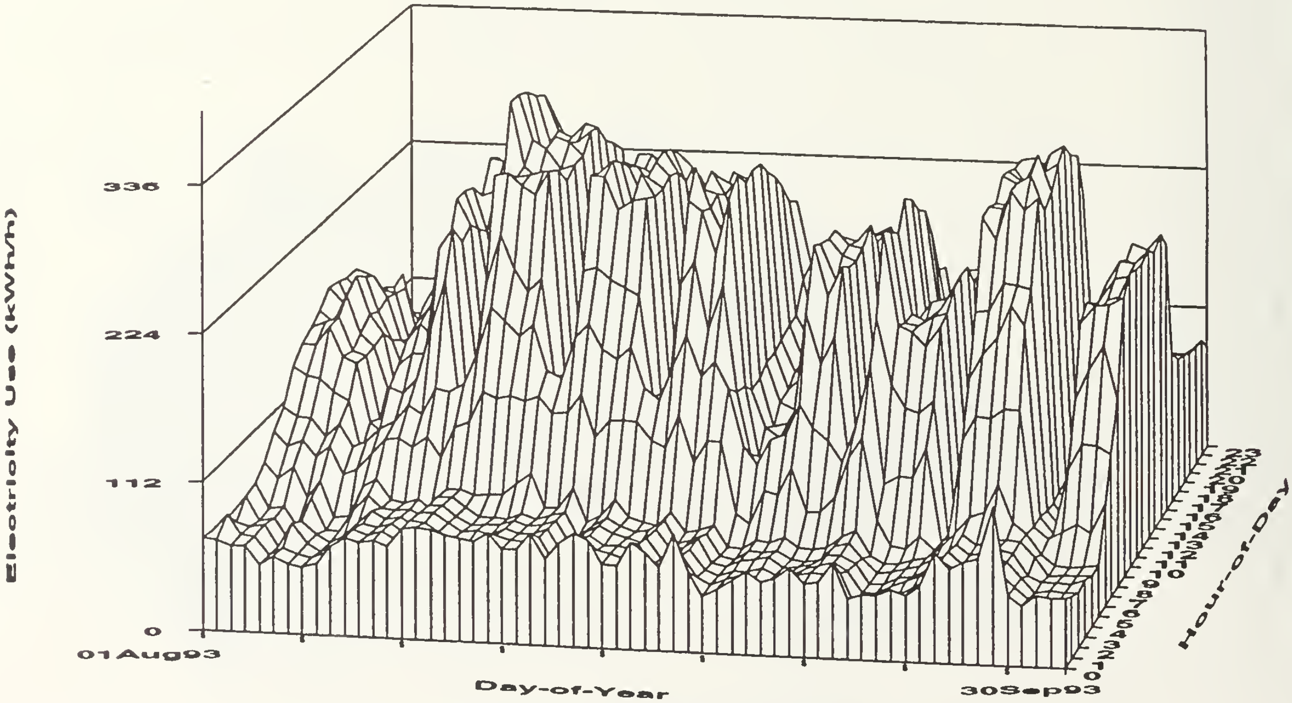
Sundays are marked with an "S"

Sims Elementary School - Fort Worth ISD - September 1992

Whole–Building Electric



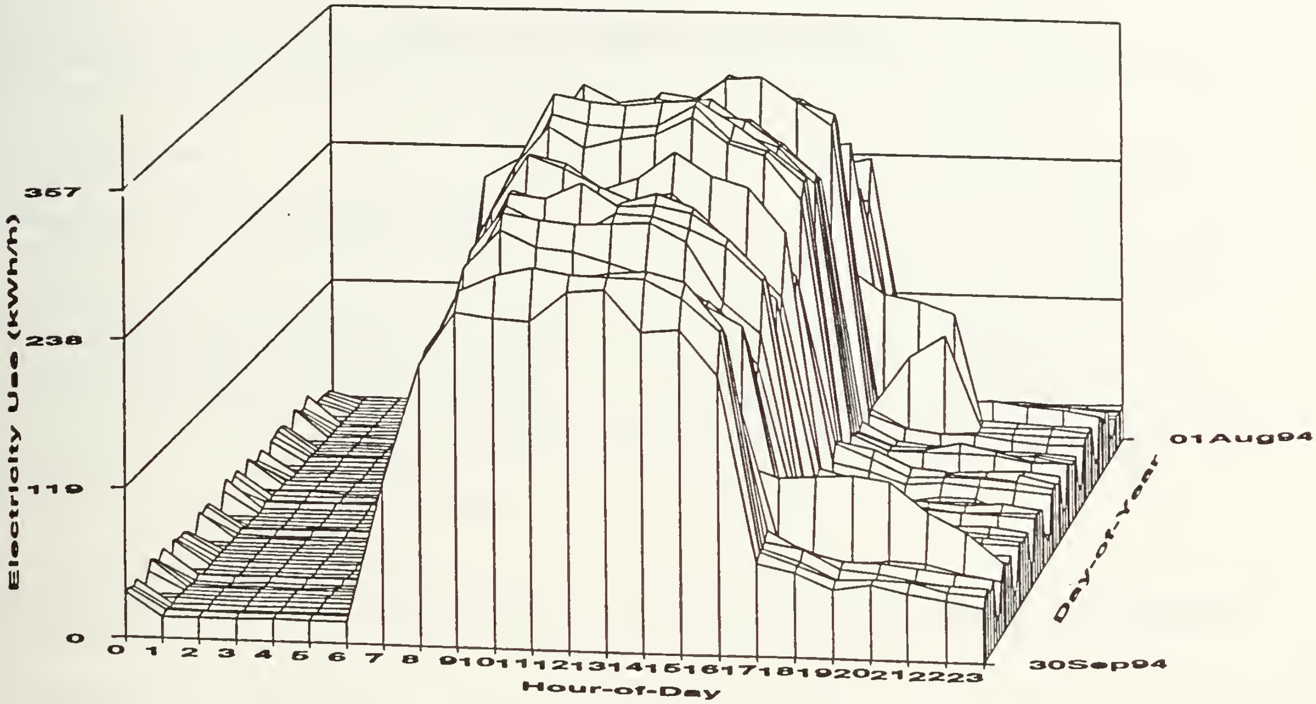
Whole–Building Electric



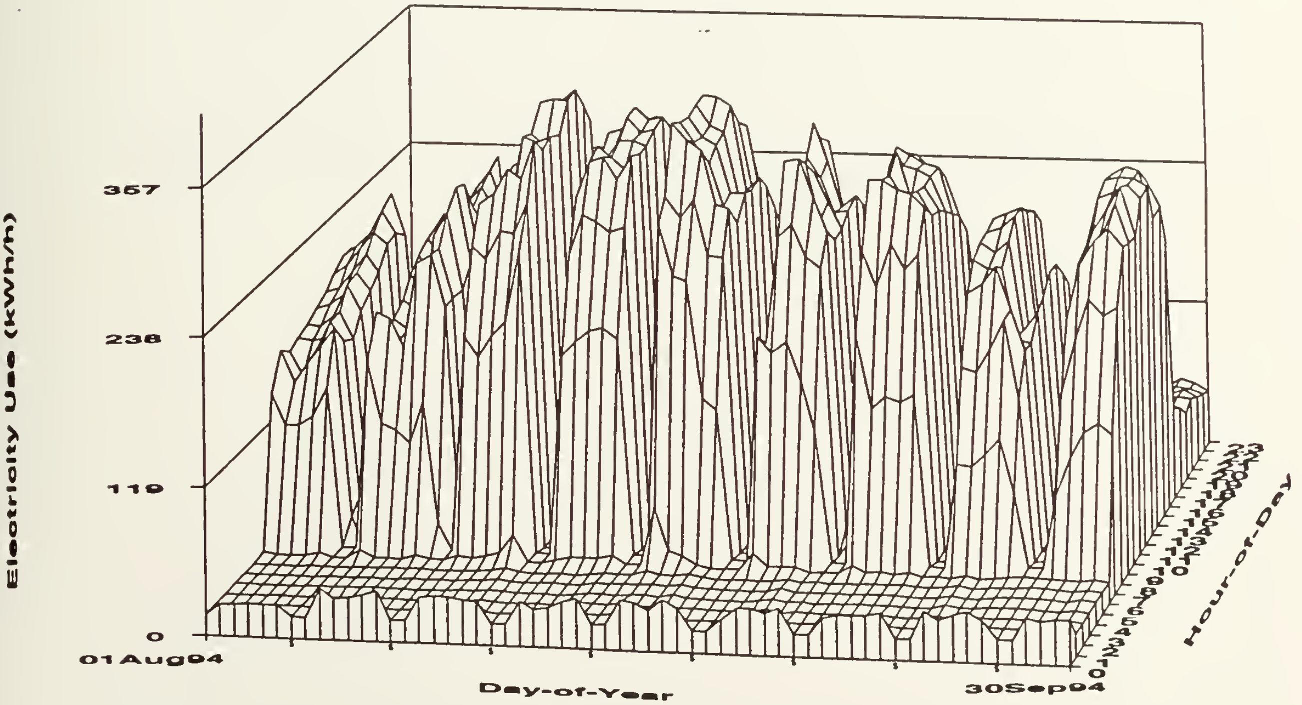
Sundays are marked with an "S"

Sims Elementary School - Fort Worth ISD - September 1993

Whole–Building Electric



Whole–Building Electric



Sundays are marked with an "S"

Tab C-5

Data Summary Notebook Information

FORT WORTH INDEPENDENT SCHOOL DISTRICT

Sims Elementary School

Building Envelope:

- 62,400 sq. ft. built in 1988
- 1-story, walls of face brick, 1/2" scathing on 6" studs, 5/8" gypsum board, and 10" concrete.
- roof built-up with tar and gravel
- windows are single pane, operable, both tinted and clear

Building Schedule:

- 7:00 am to 5 pm (M-F) closed (Sat./Sun.)
- 3 months summer break, 18+5 other holidays

Building HVAC and Equipment

- About 54 rooftop units (mostly 2/4 to 1/2 ton)
- 2 hot water heaters each 270,000 Btu/hr
- 9 1/2 hpe a exhaust fans

Lighting

- Mostly fluorescent (40 W), few PL-13 lamps

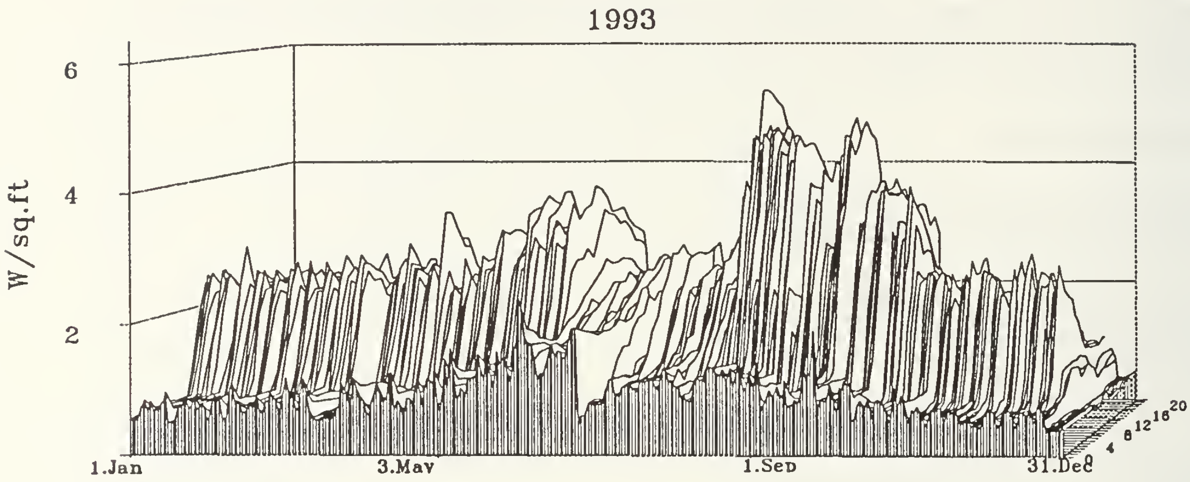
Proposed Retrofits

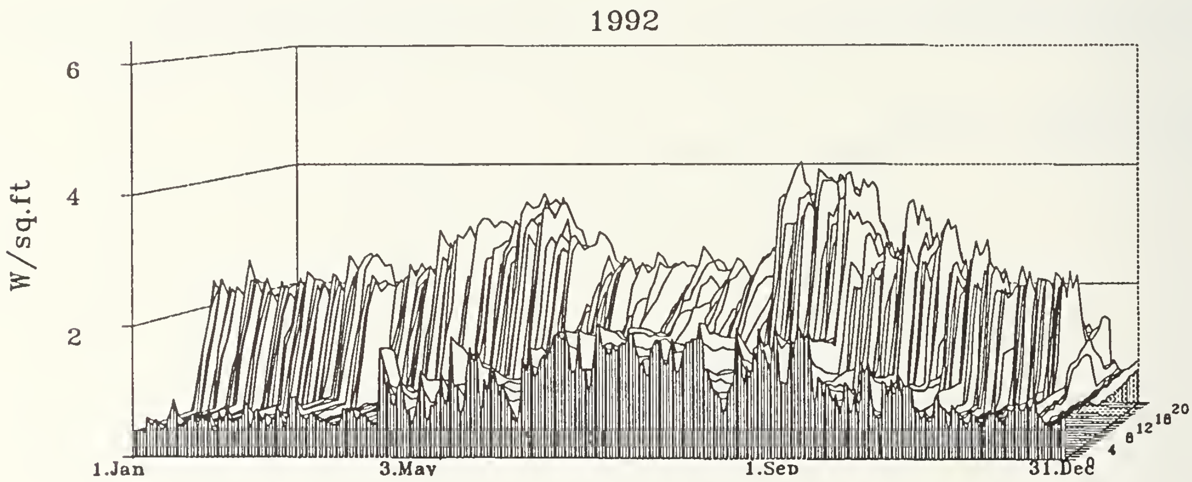
- Convert 2 X 4, 4 lamp fluorescent light fixtures to 2 X 4, 2 lamp configuration to reduce energy consumption for lights by 50

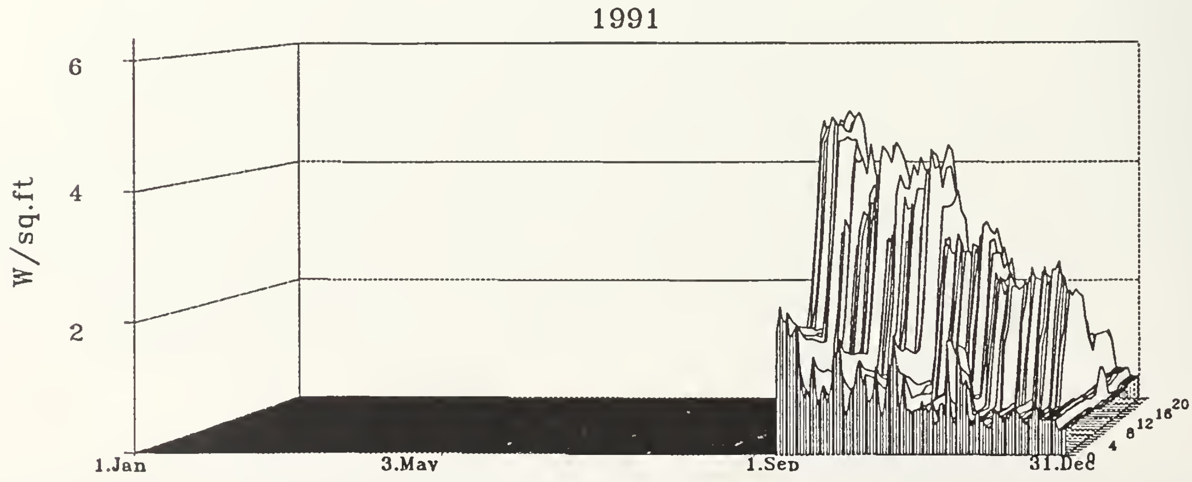
Completion Data of Report:

- Lighting modification was completed in November 91.

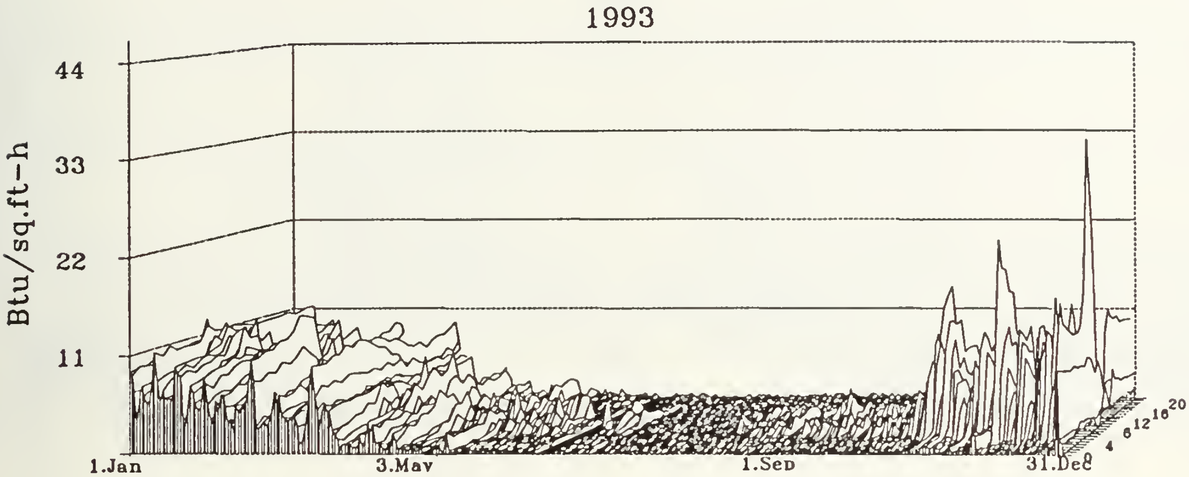
Sims Elementary School (SIM)
W.B. Electric as W/sq.ft.

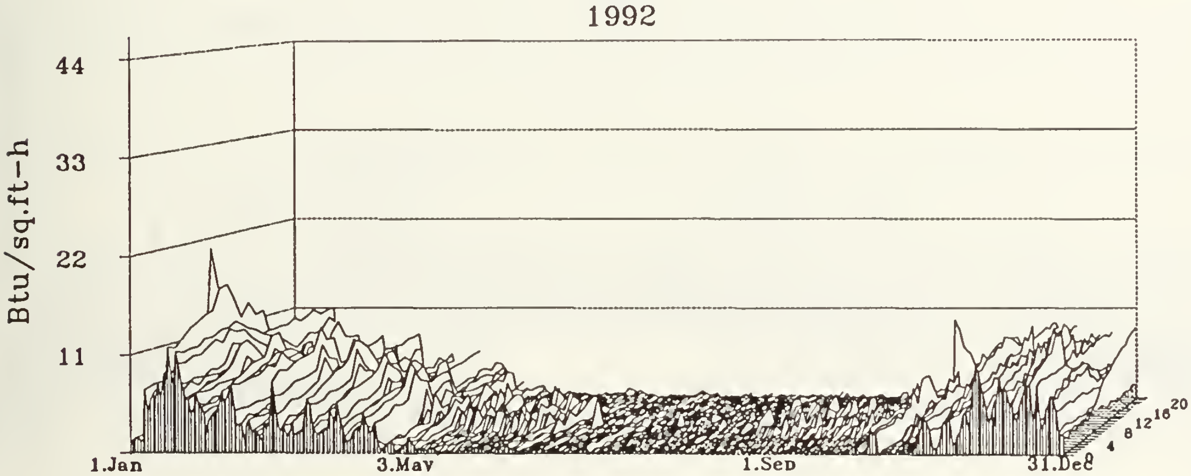


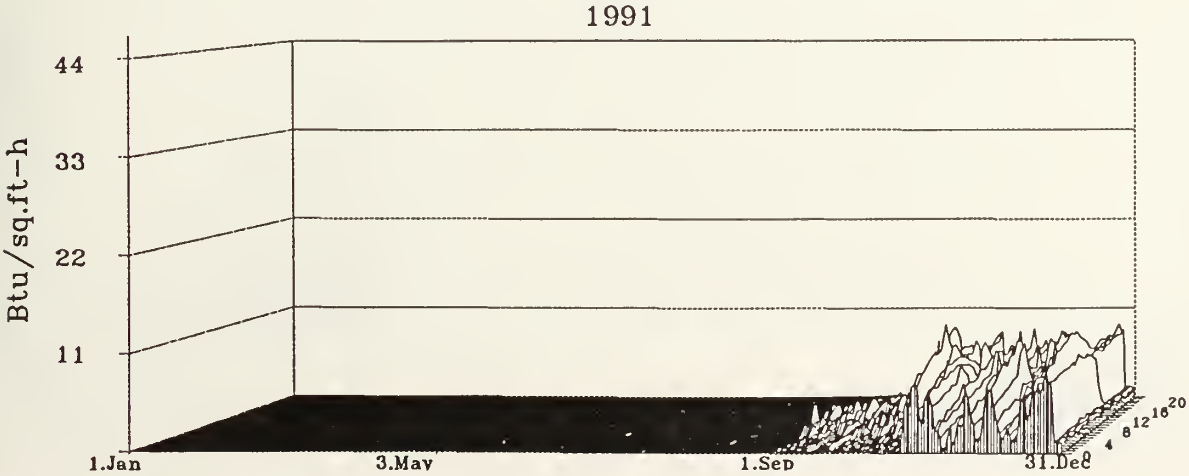




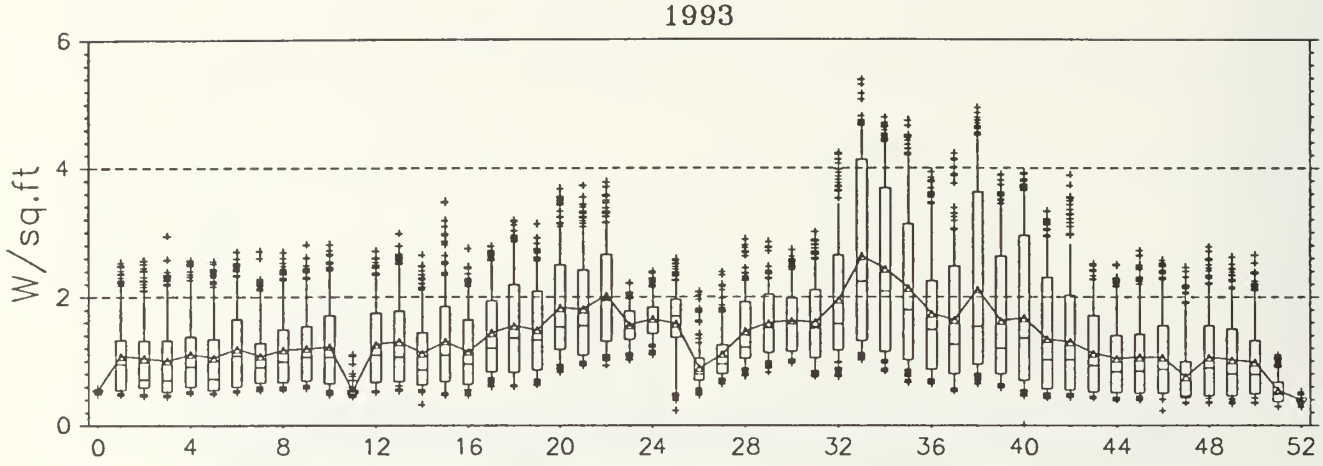
Sims Elementary School (SIM)
W.B. HW as Btu/sq.ft.-h

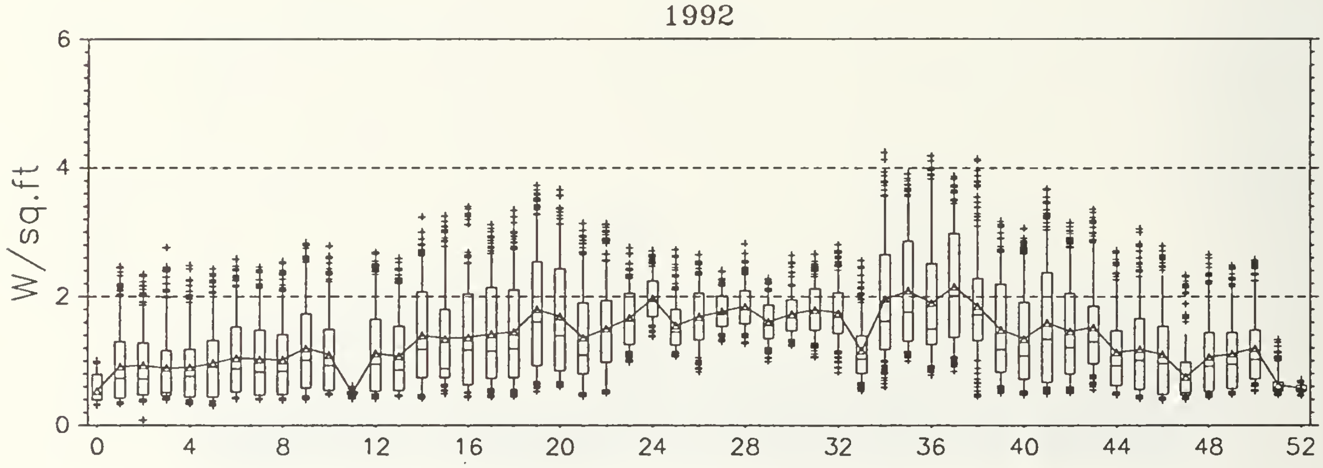


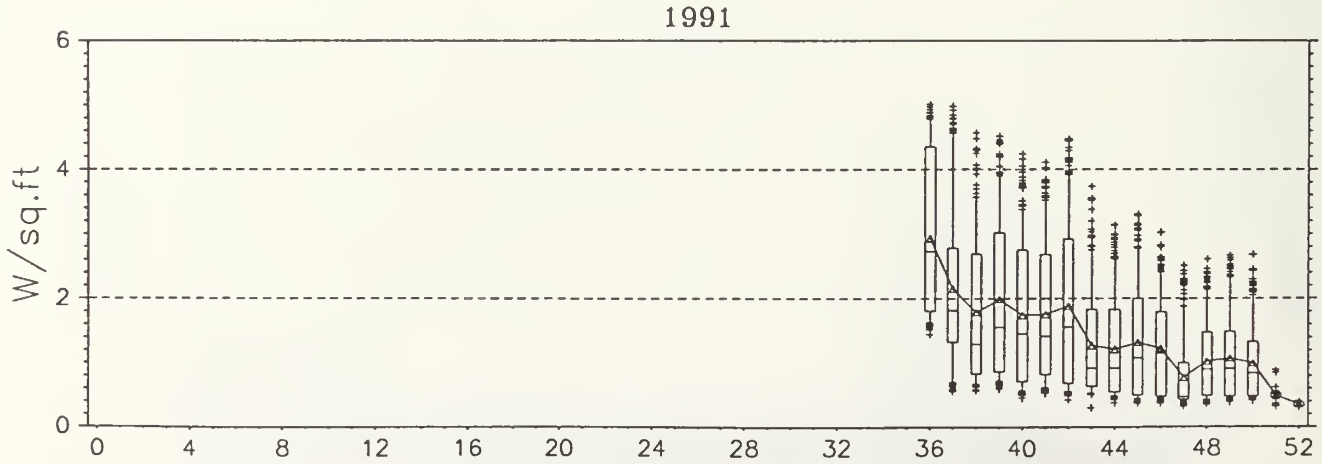




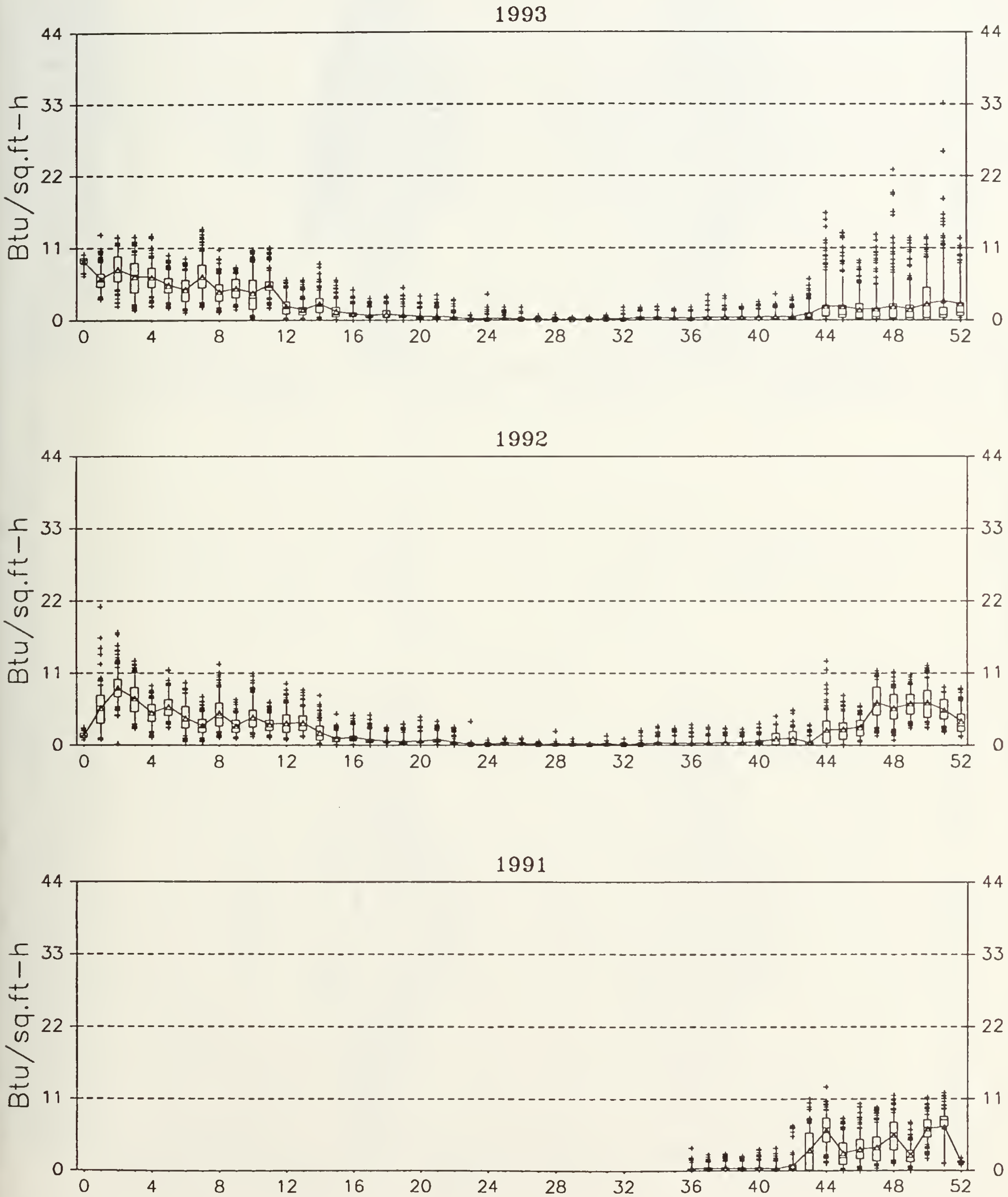
Sims Elementary School (SIM)
W.B. Electric as W/sq.ft.





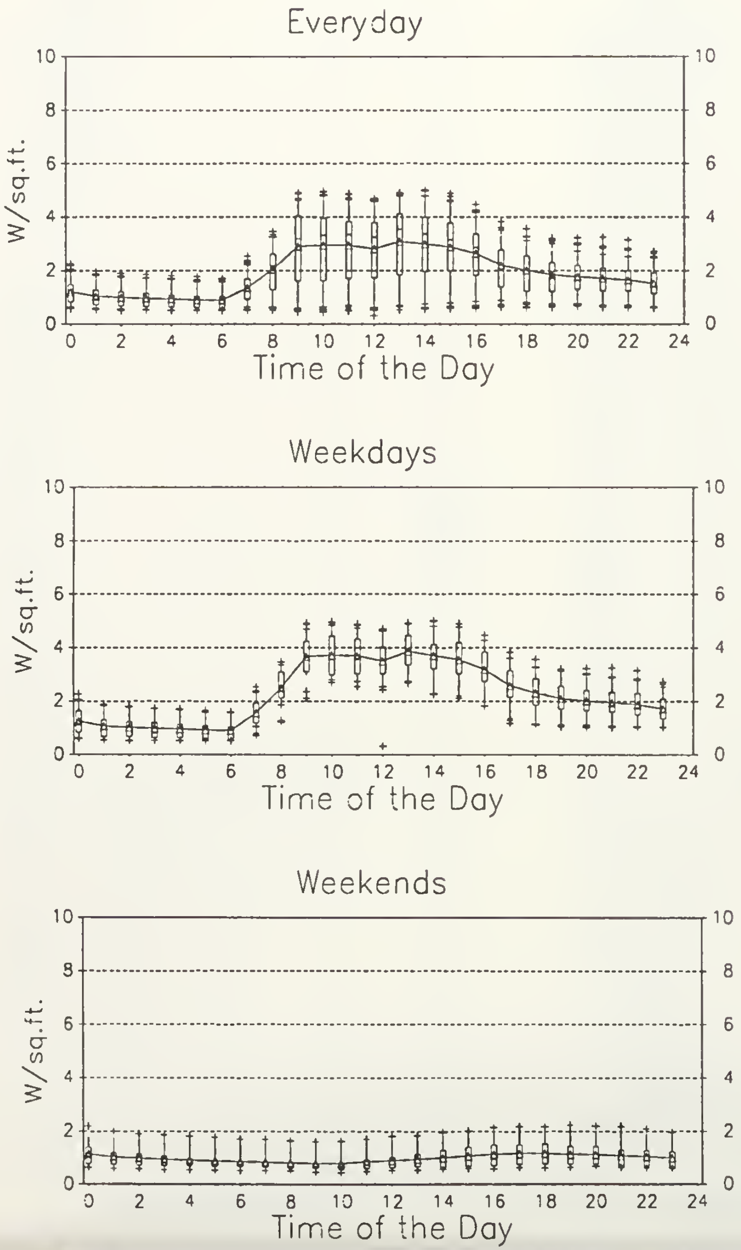


Sims Elementary School (SIM)
W.B. HW as Btu/sq.ft.-h

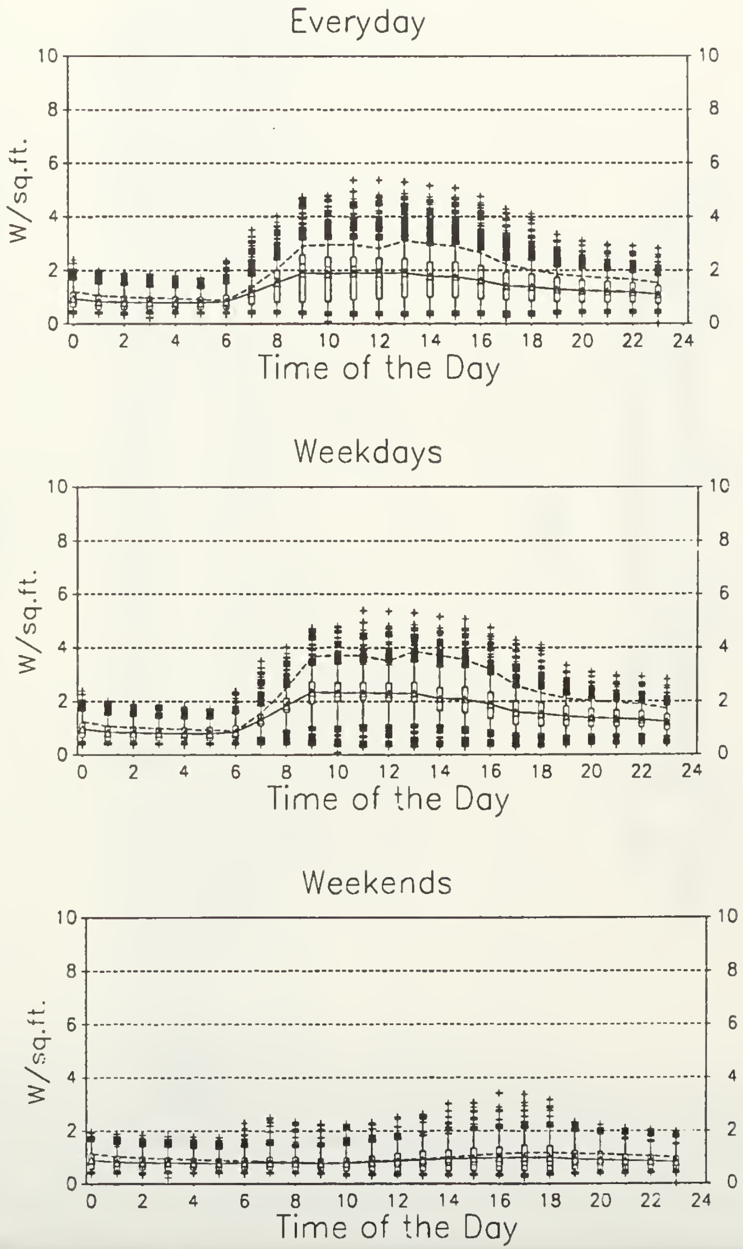


Sims Elementary School (SIM)
W.B. Electric as W/sq.ft.

Pre-Retrofit (09/10/1991 - 11/01/1991)



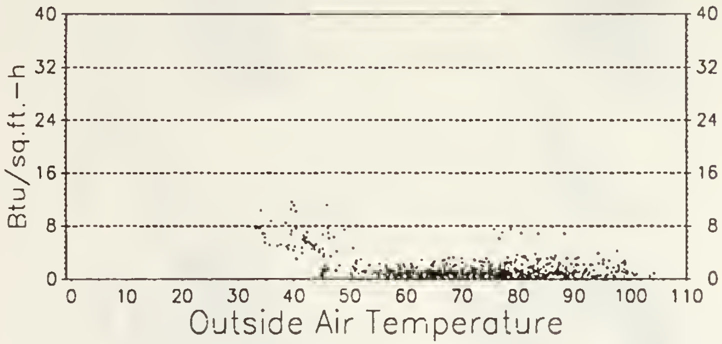
Post-Retrofit (11/23/1991 - 12/31/1993)



Sims Elementary School (SIM)
W.B. HW as Btu/sq.ft.-h

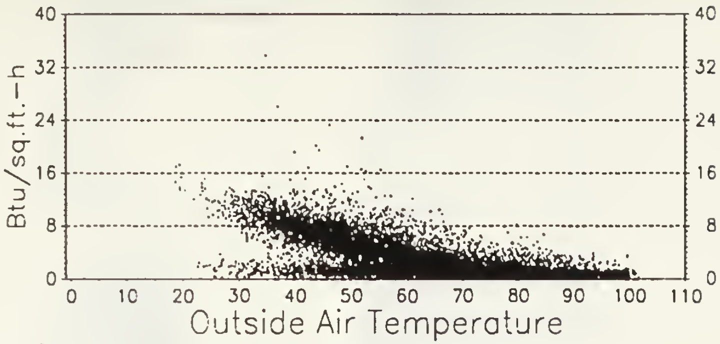
Pre-Retrofit (09/10/1991 - 11/01/1991)

Everyday



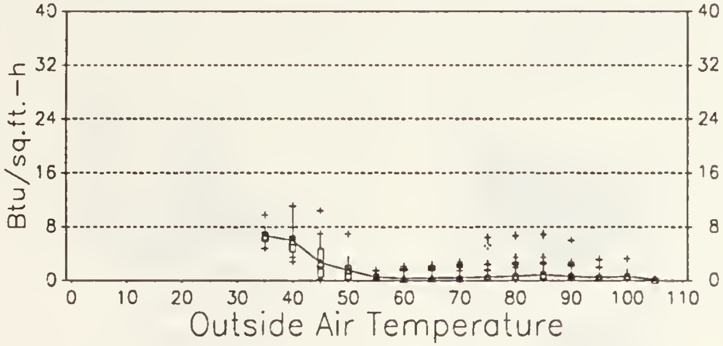
Post-Retrofit (11/23/1991 - 12/31/1993)

Everyday

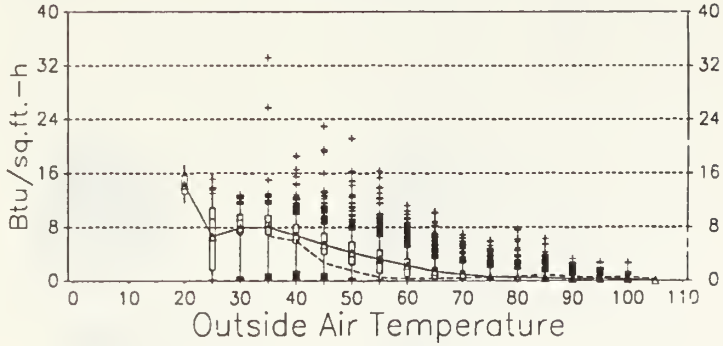


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

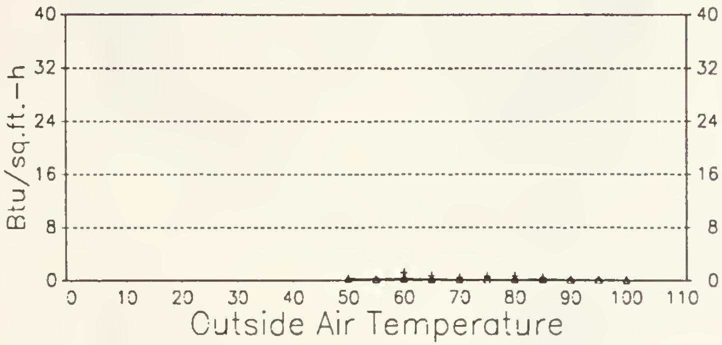
Weekdays



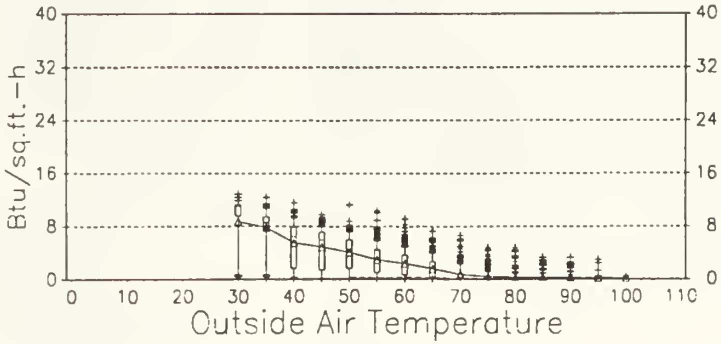
Weekdays



Weekends

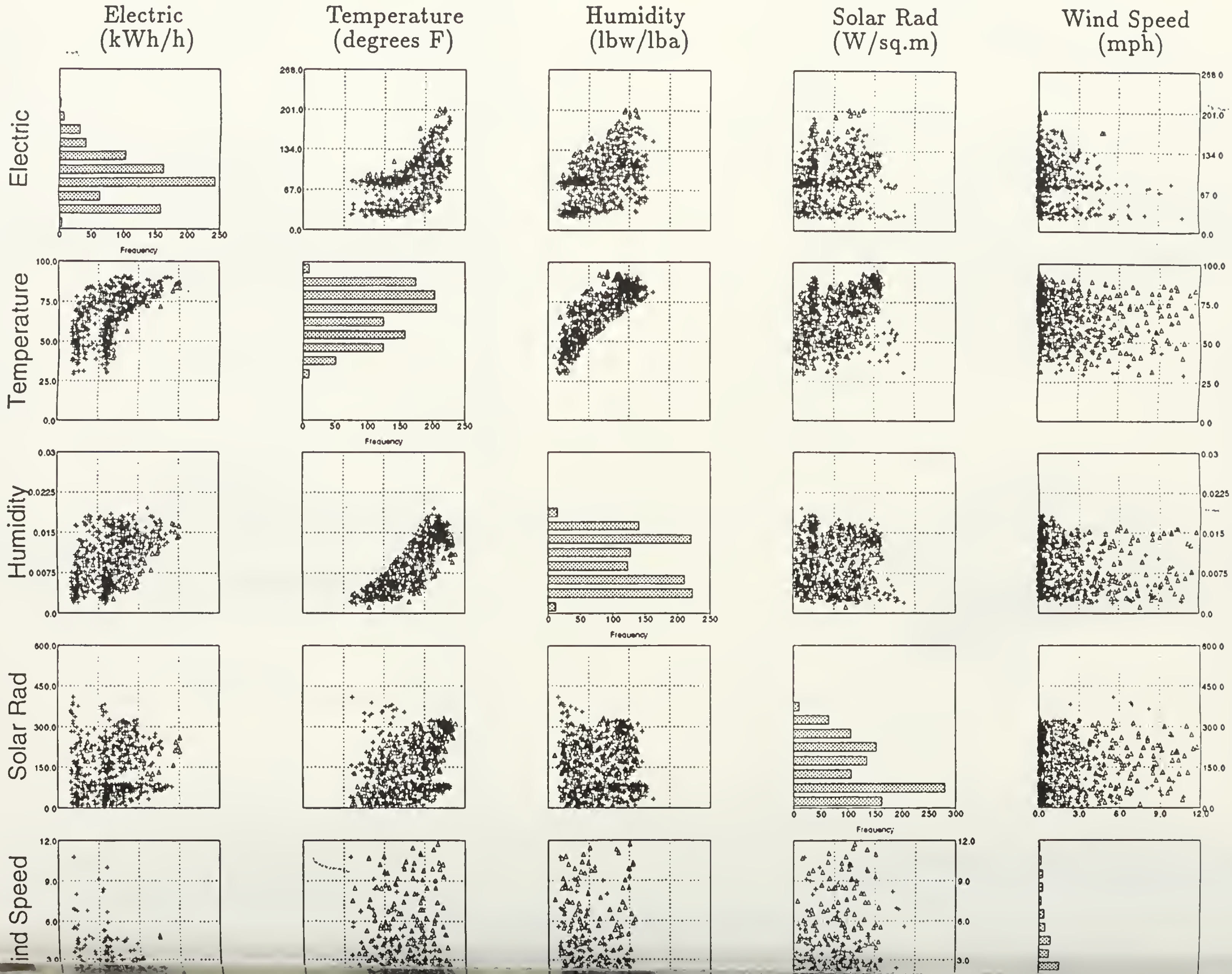


Weekends



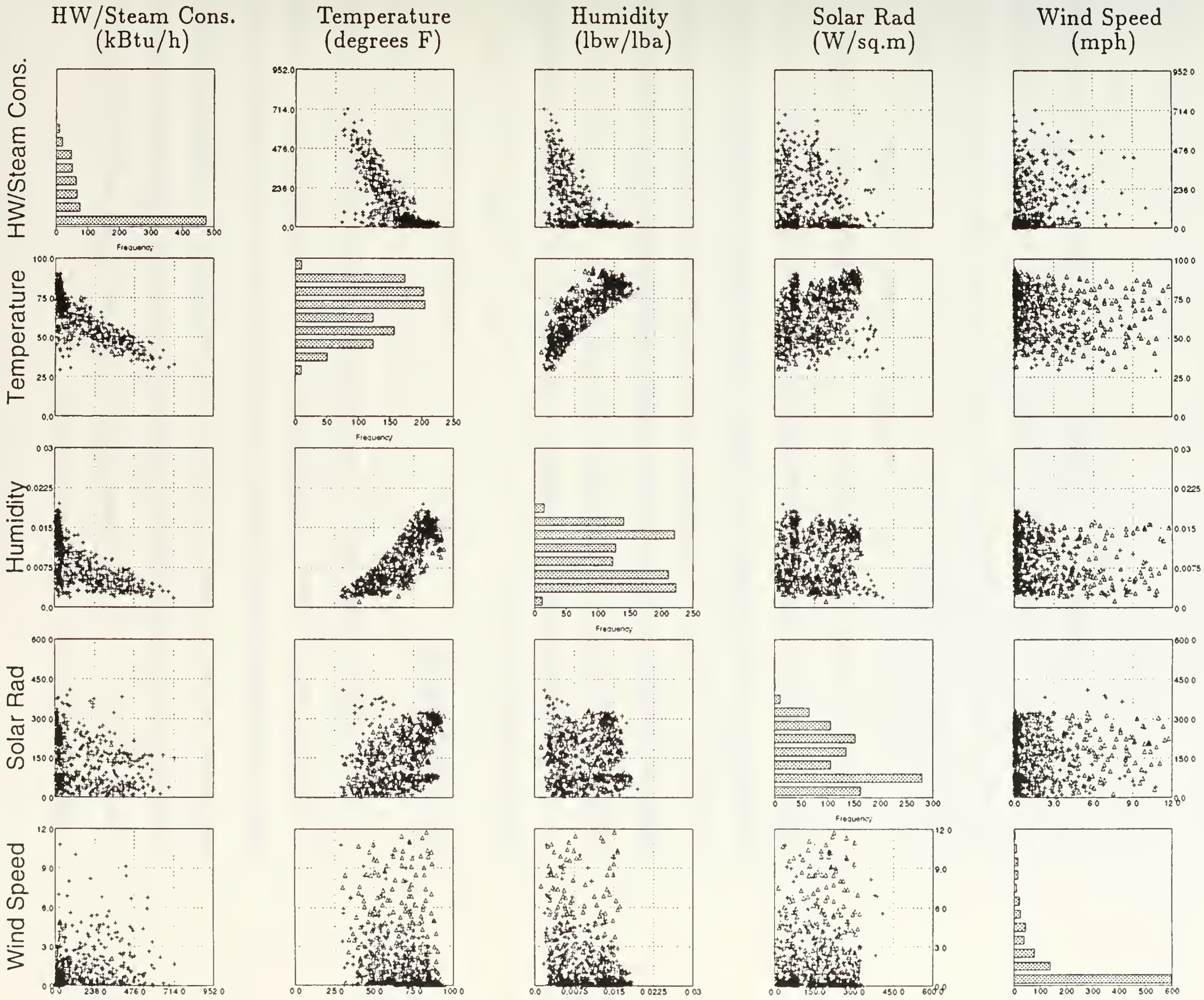
Sims Elementary School (SIM)
Daily Average Values

Pre-Retrofit (△) 09/10/1991 - 11/01/1991   Post-Retrofit (+) 11/23/1991 - 12/31/1993



Sims Elementary School (SIM)
Daily Average Values

Pre-Retrofit (△) 09/10/1991 - 11/01/1991 Post-Retrofit (+) 11/23/1991 - 12/31/1993



D. ZACHRY ENGINEERING CENTER

D.1 Site Description

The Zachry Engineering Center is located on the north side of Texas A&M University in College Station, Texas. The 3-1/2 story structure includes 324,400 square feet of conditioned space. The main functions of the building are classrooms, laboratory research, and staff offices. All HVAC systems are operated 24 hours/day, 7 days/week, year round. The building activity is very large during regular hours (6:30 a.m. to 5:30 p.m.) and slows down to a moderate pace after hours and on weekends.

Energy using systems include: chilled water, hot water, domestic hot water, and electricity. These services are provided by the Main Campus Central Plant via an underground tunnel. There are several types of air distribution systems in the building. The main system that serves 90% of the building is a double duct variable air volume arrangement, with twelve major and some smaller air handling units located along the periphery of the basement parking garage. Each of the major AHUs is equipped with a 40 horsepower supply fan, and is serving portions of the three floors.

A site summary sheet from the September 1994 MECR is included in Tab D-1. The monitoring diagrams are included in Tab D-2.

D.2 EMCS Retrofit

The audit did not make a separate recommendation for an EMCS retrofit. An EMCS to control HVAC was installed along with the recommended retrofits for this site in March of 1991. The EMCS controls the HVAC by controlling the fan speed and nighttime setbacks. The fan speed is controlled according to the demand for cooling in a particular zone. If the occupancy of a zone drops, then there is not as great of a heat load, and the fan speed slows down, thereby providing a lesser amount of cold air to that room. The nighttime setback involves changing the thermostat setpoints to a higher temperature during nighttime hours, when occupancy is greatly reduced.

D.3 Analysis

D.3.1 Data Summary Notebook[1]

The Data Summary Notebook was prepared by the Monitoring and Analysis Task of the Texas LoanSTAR program. Is was prepared to provide a historical look at all the data that have been collected for all of the LoanSTAR sites. The data are displayed in several graphical forms to show different aspects of the energy consumption behavior of a building both before and after the retrofit. These plots are analyzed for this site as a means to compare them to those prepared for the other study sites.

D.3.1.1 3-D Surface Plots

The 3-D surface plots for this site are shown in Tab D-3. The 3-D surface plots are generated using SAS[2] graphics and are displayed to show hourly data over several years. The plots show the whole building (WB) energy consumption, the total electricity consumption by motor control centers (MCC), and the whole building thermal energy use in one plot per year. The 3-D surface plots show the hours in a day on the X axis (into the page), the days of the year from left to right on the horizontal Y-axis in front of the plot, and the variable itself is the height of the plot above the X-Y plane. The plot, in effect, becomes a compilation of 365 daily 24 hour profiles.

Observations: A noticeable reduction in whole building electricity consumption can be seen at the retrofit date of March 1991. No comment can really be made about the hour of day axis, as it is very difficult to read, and it shows up on the pre/post, weekday/weekend, 24 hour BWM plots. A much more significant reduction is evident in the plots for the Motor Control Center (from approximately 380 kWh/h to approximately 200 kWh/h). The daily profile changes from basically constant consumption to low nighttime consumption with higher daytime consumption. Again, this is hard to read on this plot. As chilled water and hot water usage were not studied in the other test sites, no comparisons with other sites can be made. However, the plots are included for completeness.

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[1] Data Summary Notebook for Site 001, Zachary Engineering Center
[2] Base SAS Software, SAS Institute, Inc., Cary NC 27512-8000

Comparison: For the other study sites, 2-D energy consumption plots were used to show daily consumption versus day of the year. The hourly consumption was averaged over certain sort parameters and plotted as hourly consumption versus hour of day.

D.3.1.2 Weekly Box Whisker Mean (BWM) Plots

Weekly Box Whisker Mean Plots for this site are shown in Tab D-4. The weekly BWM plots are arranged in the same manner as the 3-D surface plots to facilitate a comparison between pages. To generate the weekly BWM plots, the data are first grouped into 52 weeks. Each week starts on a Sunday and ends on a Saturday. The BWM symbol efficiently displays the means, the 10th, 25th, 50th, 75th, and the 90th percentiles and all the outliers above the 90th percentile and below the 10th percentile. The box extends from the 25th (first quartile) to the 75th (third quartile) percentile. The whiskers extend from the top of the box to the 90th percentile and from the bottom of the box to the 10th percentile. The median (50th percentile) is marked inside the box with a single cross hatch. Values less than the 10th percentile and greater than the 90th percentile are marked as pluses (+), which lie below or above the whiskers. Means for each week are superimposed as triangles and joined by a line.

Observations: As would be expected, the weekly consumption also drops at the retrofit date of March 1991. More information is provided in these plots than in the 3-D surface plots. Here, statistical data is included in the form of BWM plots.

Comparison: Weekly data was not analyzed in the other sites.

D.3.1.3 Pre/Post, Weekday/Weekend, 24-hour BWM Plots

The pre/post, weekday/weekend, 24 hour BWM plots for this site are shown in Tab D-5. To generate these plots, the data are first separated into pre-retrofit and post-retrofit periods. Within each period, the data are grouped into weekdays and weekends. The whole building electricity (WB Electric) consumption, as W/sf, is plotted as 24-hour BWM plots against the time of the day for: (1) each day (regardless of weekdays or weekends), (2) weekdays only, and (3) weekends only for both the pre-retrofit

and the post-retrofit periods. In addition, the mean lines from the pre-retrofit panels are superimposed as dashed lines on the post-retrofit panels to show the changes in the hourly profiles due to the retrofit.

Observations: In all three plots (everyday, weekdays and weekends), a reduction in whole building electricity is evident. In each post-retrofit plot, the line connecting the means of each data point is below the superimposed pre-retrofit line (dashed line). The reduction is fairly constant across all hours of the day.

Comparison: There are a number of differences between these plots and the hourly average plots used for the other sites. First, there is an additional category in the average hourly plots, which is semester/non-semester. This is an important sort category because for many sites, the average consumption during the semester periods varies greatly from the average consumption during the non-semester periods. As consumption is different between these two periods, it is useful to study them separately. Secondly, the consumption units are different (W/sf for BWM plot versus kWh/h for the average hourly consumption plots. It is useful to convert the units to W/sf for the sake of comparing with other sites, which may be significantly different in size. Lastly, the BWM plot is more effective in showing the statistical variation in the data, but it is also difficult to read.

D.3.1.4 Pre/Post, Weekday/Weekend, BWM Temperature Binned Plots

The pre/post, weekday/weekend, BWM temperature binned plots for this site are shown in Tab D-6. For thermal loads, such as the chilled water consumption and steam/hot water consumption, the weekday and weekend energy consumption is grouped into 5 °F temperature bins and plotted as BWM plots against the ambient temperature. These same data are also plotted as scatter plots to show the general trend and density of the data points. The data for the scatter plots are slightly jittered to improve graphical presentation. Jittering is a graphical enhancement that improves a plot by adding a random noise to one of the variables. Jittering is necessary when BTU data are plotted because data are recorded in large increments, which causes severe data overlap when plotted.

Observations: There is a noticeable reduction in whole building chilled water and whole building hot water consumption. Although these were not analyzed in the other study sites, they provide an additional way to view the data.

Comparison: Chilled water and hot water consumption were not studied in the other sites.

D.3.1.5 Carpet Plots of Energy Use versus Ambient Conditions with Juxtaposed Histograms

Carpet plots of energy use versus ambient conditions are shown in Tab D-7. Carpet plots show the daily averaged pre/post data plotted against several variables. Separate symbols are used for the pre-retrofit (triangle) and post-retrofit (plus) periods. The carpet plot is arranged so that relationships between energy consumption and several weather variables (ambient temperature, humidity, global horizontal solar radiation, and wind speed) can be simultaneously viewed. In the carpet plot shown, energy consumption is shown along the top row and the left most column. Other panels show the interaction among the weather variables. The panels along the diagonal show the frequency distribution of all the data points within bins.

Observations: These plots are very small and hard to read, but show various trends in data.

Comparison: No comparisons can be made as these plots are not used for the other study sites.

D.3.1.6 Carpet Plots of One Energy Channel Use Against Other Energy Use Channels

Carpet plots of one energy channel use against other energy use channels are shown in Tab D-8. These are specialty carpet plots where one energy use is plotted against other energy use channels. In the plot shown, lights and receptacle (L&R) electricity use is a derived channel which is obtained by subtracting the MCC electricity use from the whole building electricity use. These carpet plots are helpful in determining interactions between one energy use, such as chilled water consumption, and another, such as steam/not water consumption in both the pre-and post-retrofit periods.

Observations: These plots are very small and hard to read, but show trends in data.

Comparison: No comparisons can be made as these plots are not used for the other study sites.

D.3.1.7 Coincident Cumulative Frequency Plots

Coincident cumulative frequency plots for this site are shown in Tab D-9. The coincident cumulative frequency plot shows the whole building electricity consumption and the coincident electricity consumption by the Motor Control Centers (MCC). To produce these plots, data are first separated into pre- and post-retrofit periods and sorted into descending order of whole building electricity consumption. The data is then plotted from the highest to the lowest consumption along with the coincident MCC electricity consumption. This plot is generally useful to show the drop in whole building and MCC electricity consumption due to a VAV retrofit.

Observations: These plots show a definite decrease in both whole building electricity and MCC electricity consumption.

Comparison: No comparisons can be made as these plots are not used for the other study sites.

Tab D-1

Site Summary Sheet

TEXAS A&M UNIVERSITY

Zachry Engineering Center

Building Envelope:
- 324,400 sq.ft
- 3-1/2 floors and a ground floor level, erected 1973, classes, offices, labs, computer facility, and clean rooms for Solid State Electronics
- walls: cement block
- windows: 12% of total wall area
  single pane with built-in-place vertical blinds
- roof: flat

Building Schedule:
- classrooms and labs: 7:30 am to 6:30 pm weekdays
- offices: 7:30 am to 5:30 pm weekdays
- computer facility: 24 hrs/day

Building HVAC:
- 12 variable volume dual duct AHUs (12-40hp)
- 3 constant volume multizone AHU (1-1 hp, 1-7hp, 1-10hp)
- 4 constant volume single zone AHU (4-3hp)
- 10 fan coils (10-0.5 hp)
- 2 constant volume chilled water pump (2-30hp)
- 2 constant hot water pump (2-20hp)
- 7 misc. pumps (total of 5.8hp)
- 50 exhaust fans (50-0.5hp)

HVAC Schedule:
- 24 hrs/day

Lighting:
- fluorescent

Retrofits Implemented:
- control modifications to the dual duct system
- variable volume dual duct system

Other Information:
- EMCS system to control HVAC was also installed along with the retrofits.

Date of Retrofits:
- date of completion for VAV and control modifications to the dual duct system: 03/05/91.

Savings Calculations:
- estimated savings are average monthly savings from the audit report (total annual savings divided by 12).

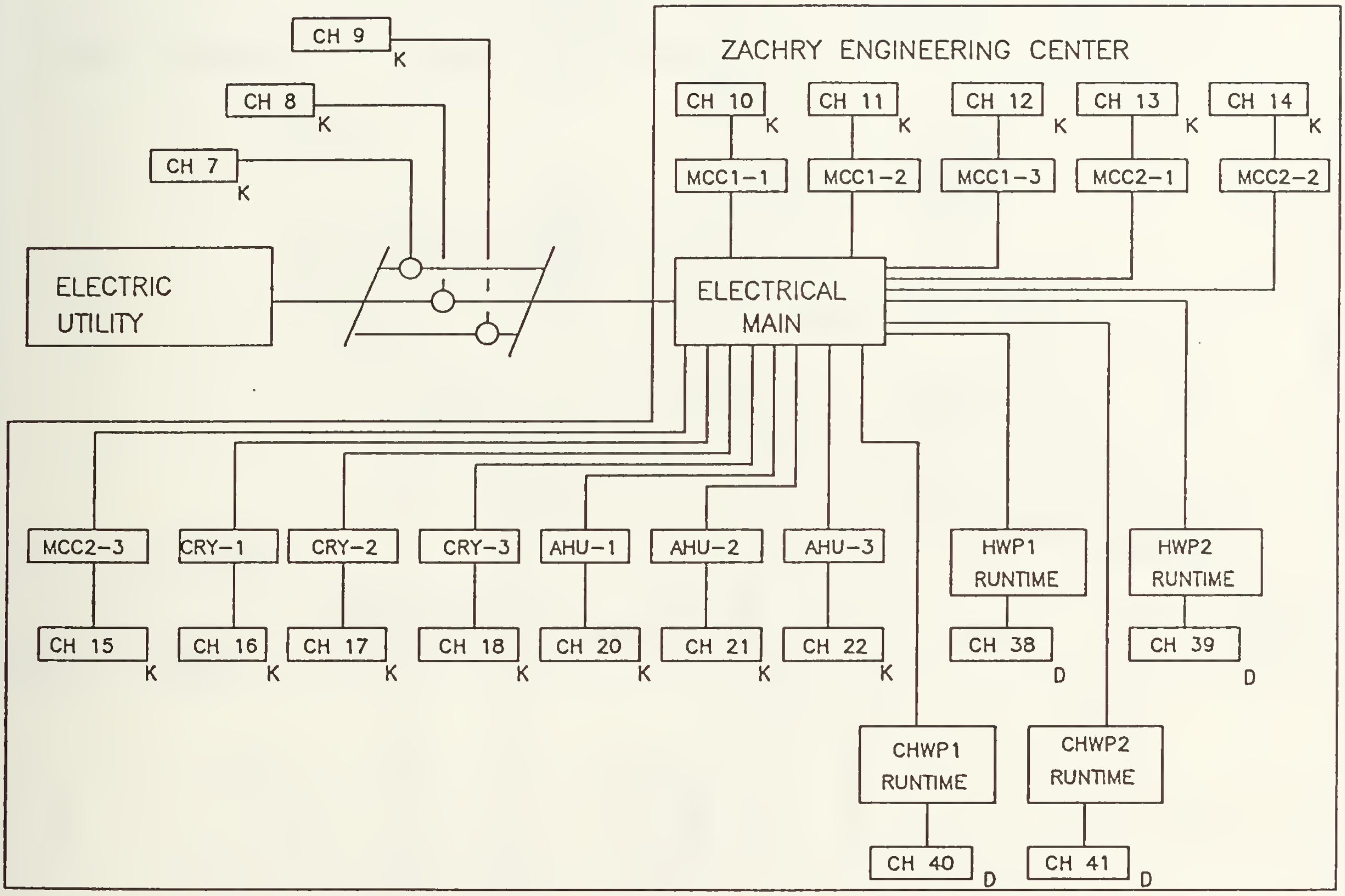
Tab D-2

Monitoring Diagrams

ELECTRICAL MONITORING DIAGRAM
ZACHRY ENGINEERING CENTER

LEGEND

K–KWH CHANNEL
A–ANALOG CHANNEL
D–DIGITAL CHANNEL

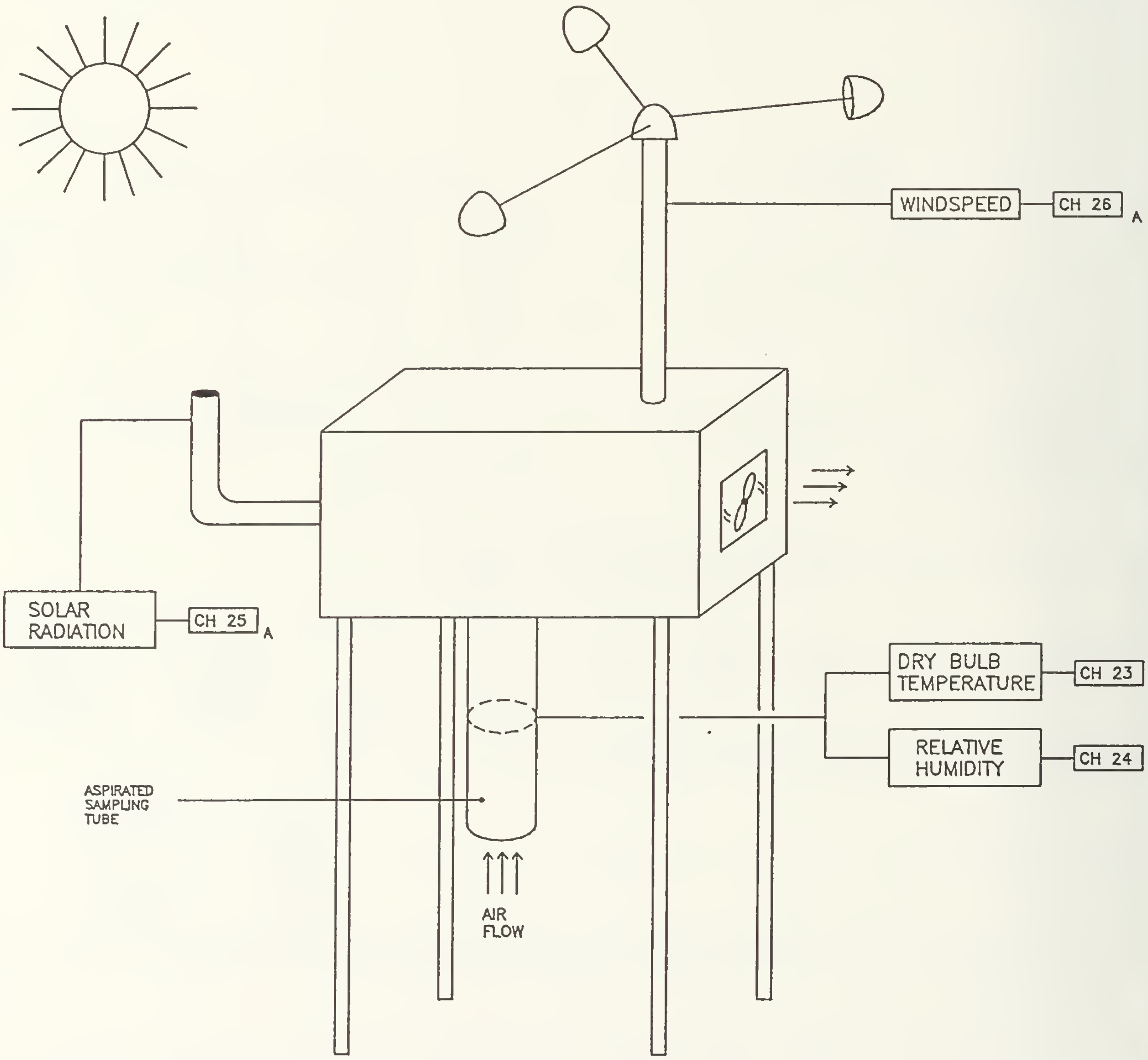


ZACHRY ENGINEERING CENTER – SITE 001

WEATHER MONITORING DIAGRAM
ZACHRY ENGINEERING CENTER

LEGEND

K=KWH CHANNEL
A=ANALOG CHANNEL
D=DIGITAL CHANNEL
PC=PUMPED CONDENSATE

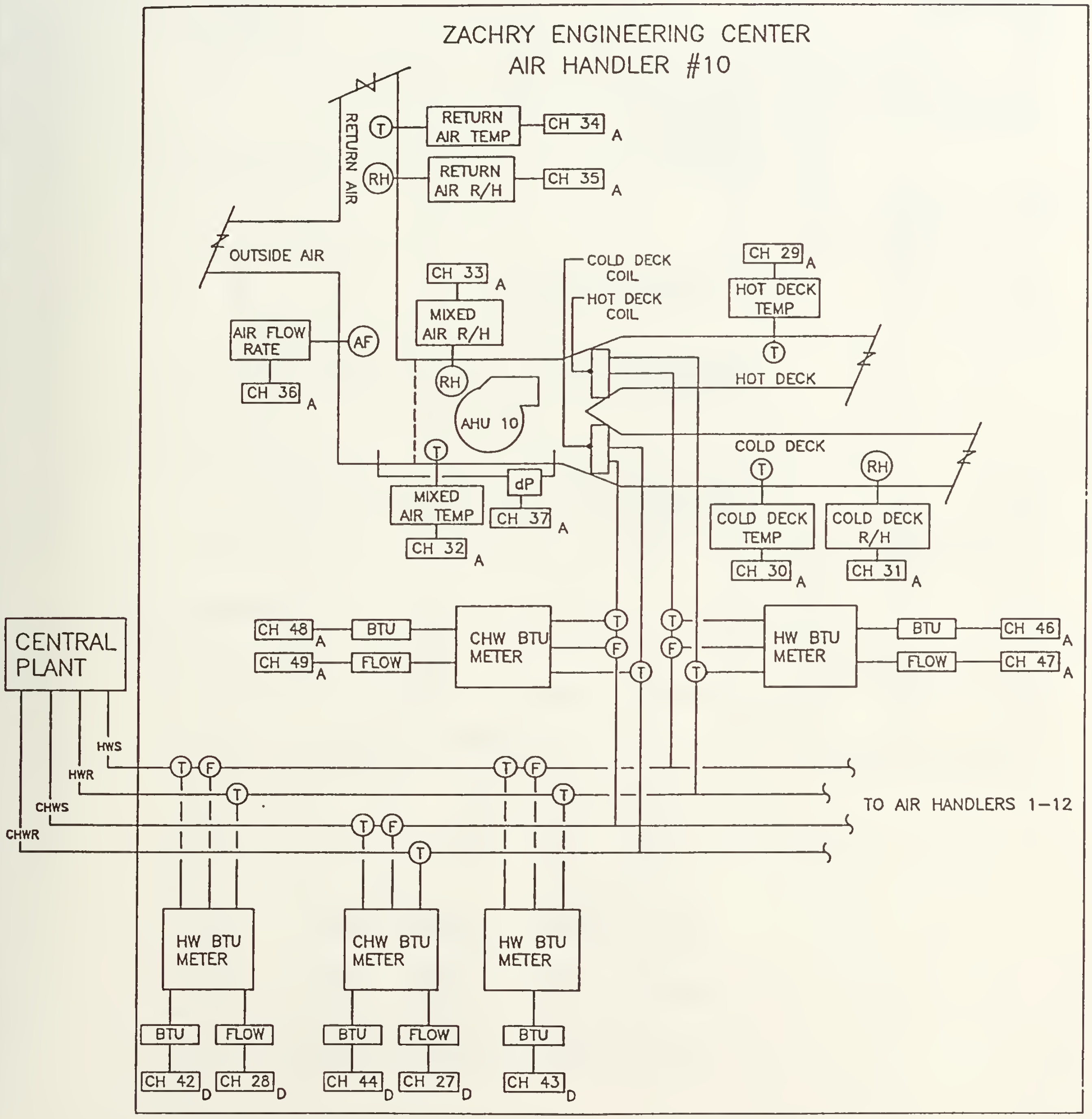


ZACHRY ENGINEERING CENTER – SITE 001

THERMAL MONITORING DIAGRAM
ZACHRY ENGINEERING CENTER

LEGEND

K–KWH CHANNEL
A–ANALOG CHANNEL
D–DIGITAL CHANNEL
PC–PUMPED CONDENSATE



ZACHRY ENGINEERING CENTER – SITE 001

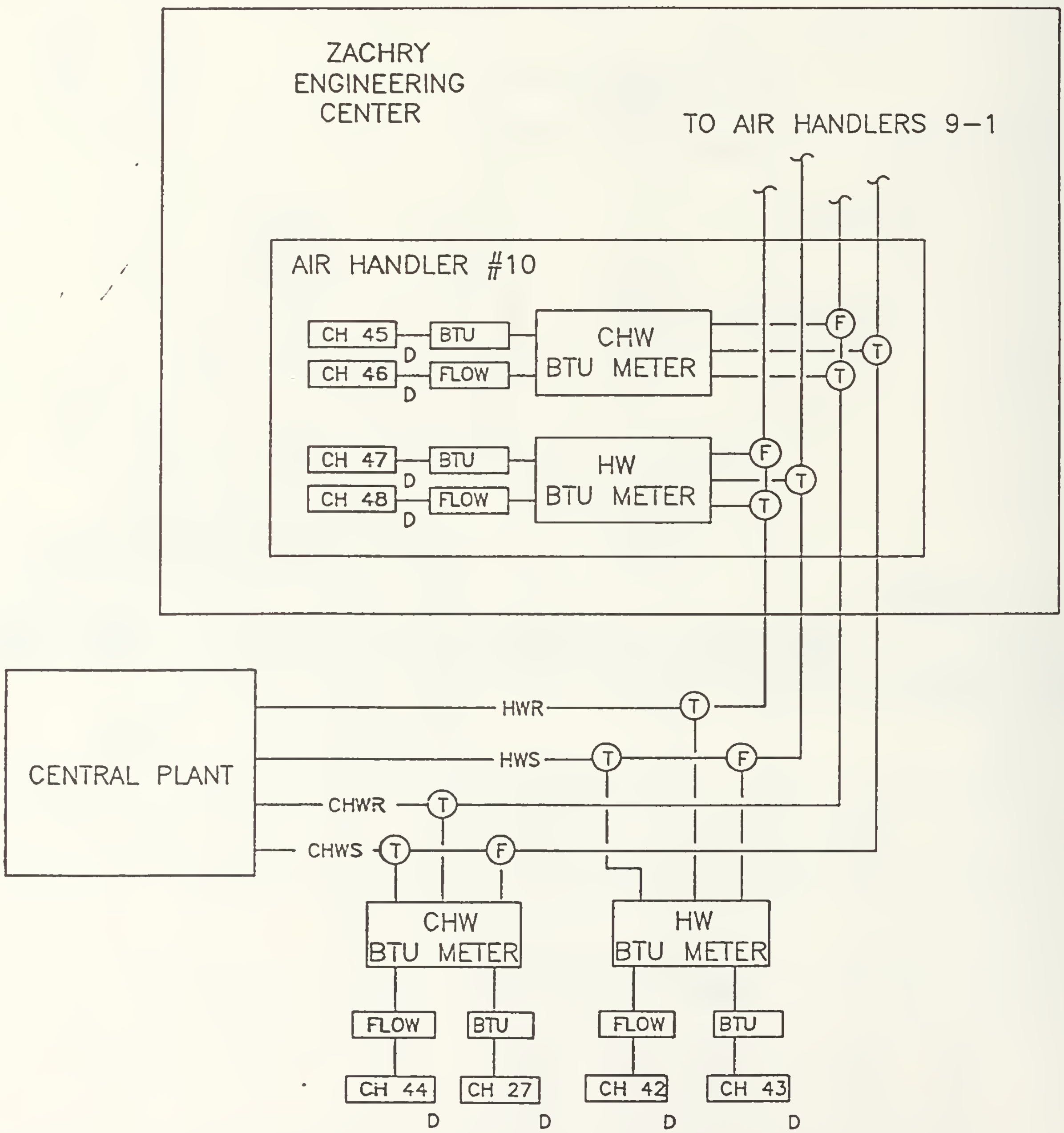
received
7-6-93

THERMAL MONITORING DIAGRAM

ZACHRY ENGINEERING CENTER

LEGEND

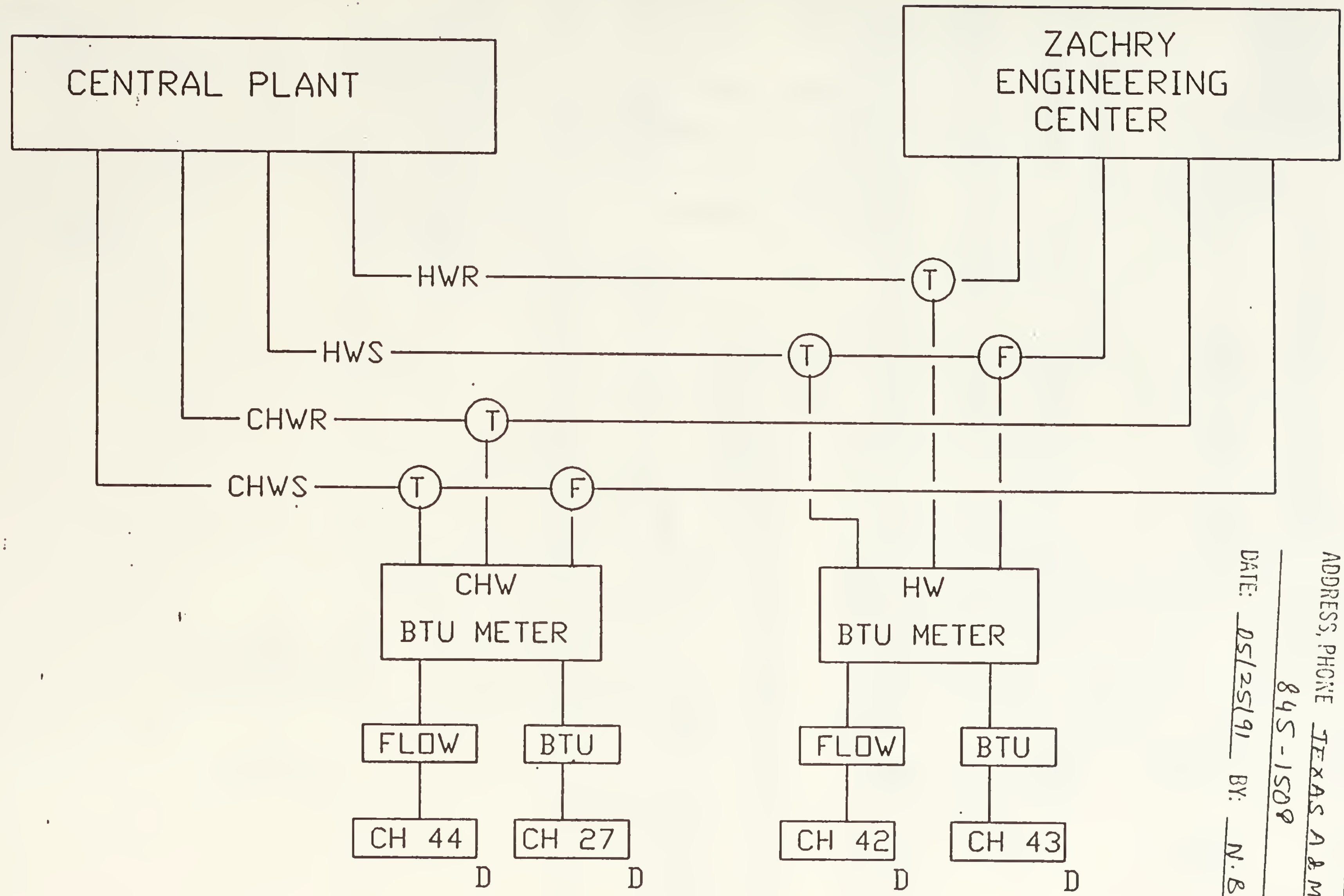
K-KWH CHANNEL
A-ANALOG CHANNEL
D-DIGITAL CHANNEL



ZACHARY ENGINEERING CENTER - SITE 001

THERMAL MONITORING DIAGRAM A

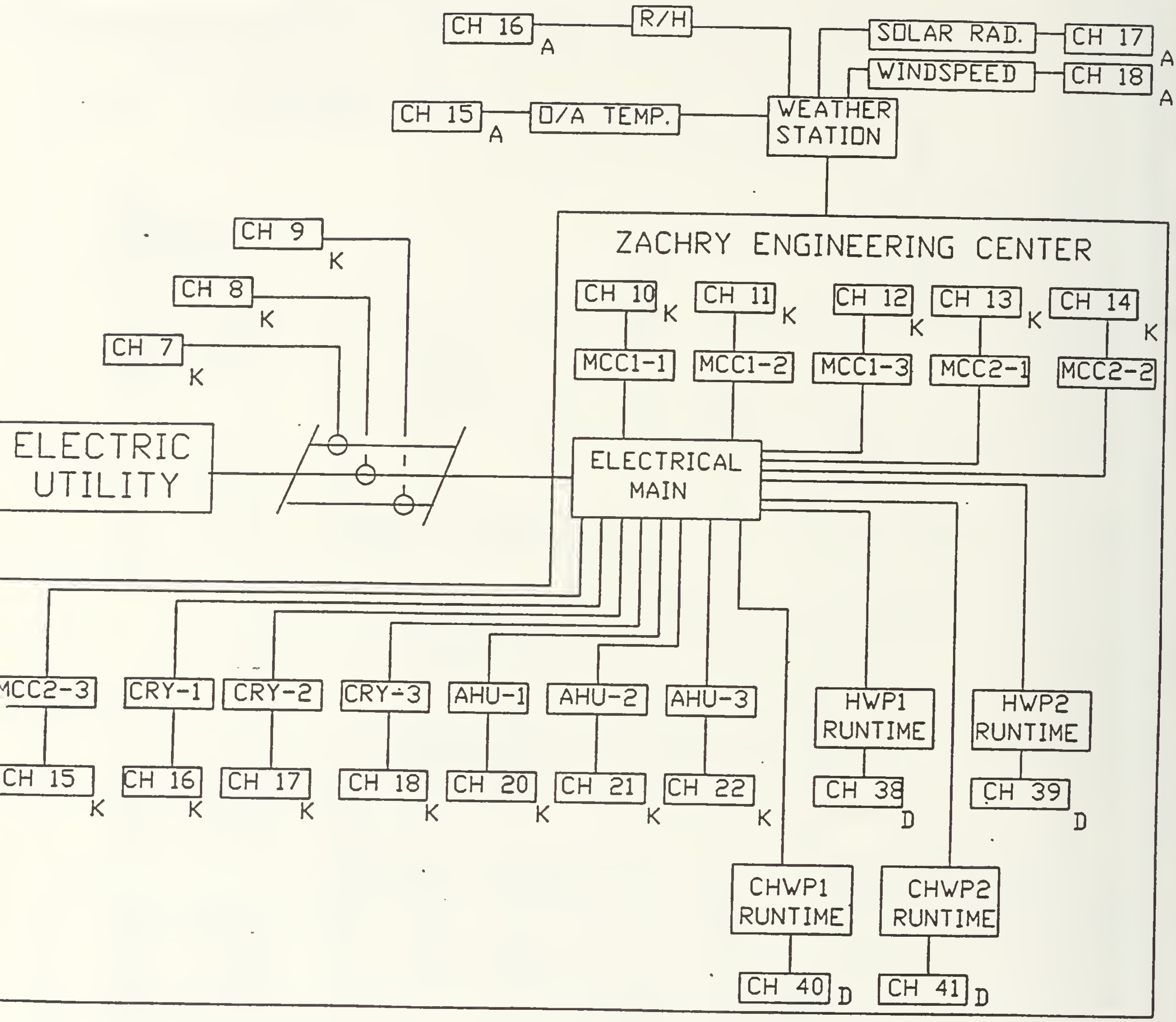
ZACHRY ENGINEERING CENTER



SOURCE: Keith Boles
ESL, MECH. ENGG DEPT
ADDRESS, PHONE TEXAS A & M UNIV
845-1508
DATE: 05/25/91 BY: N. B.

KWH MONITORING DIAGRAM

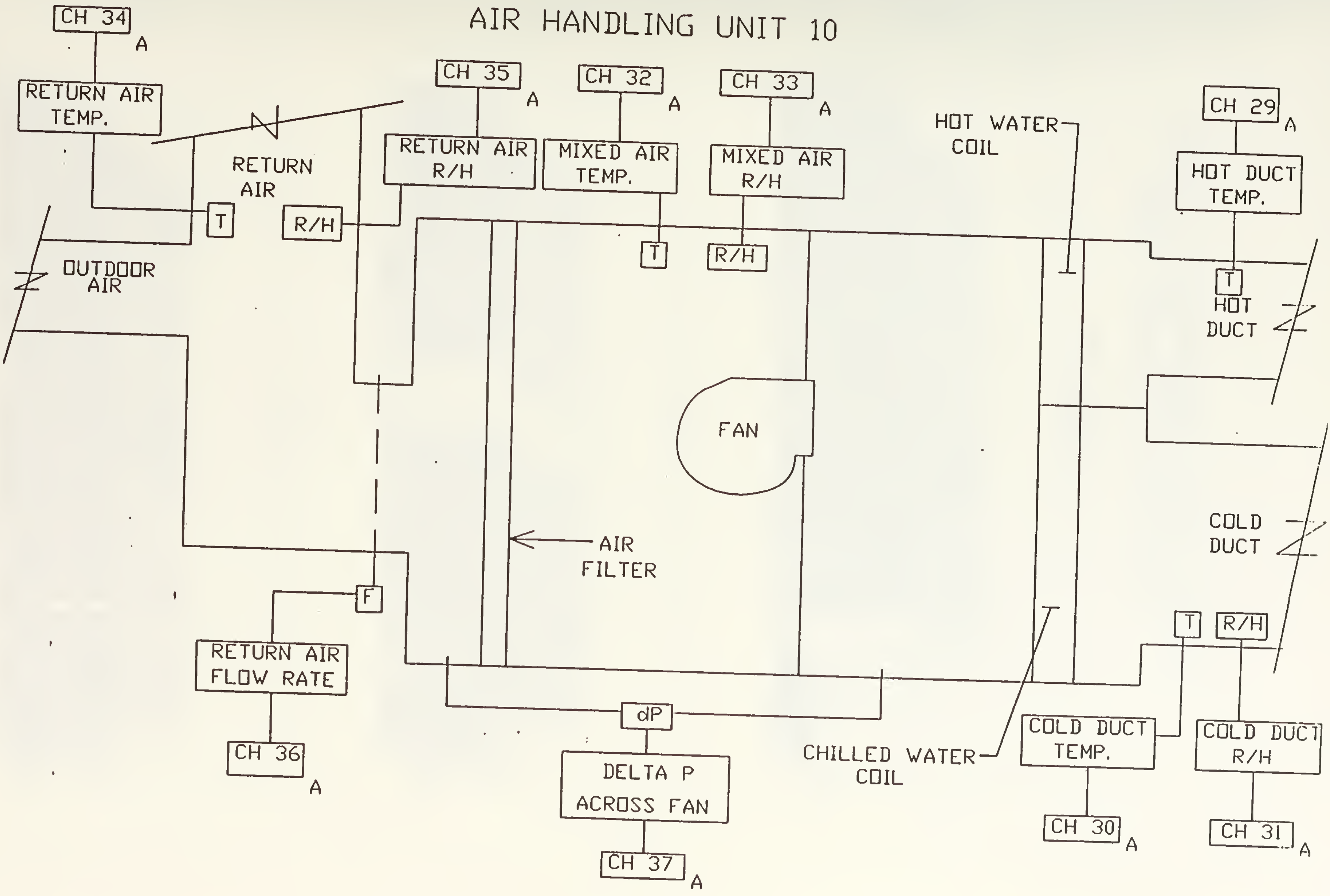
ZACHRY ENGINEERING CENTER



... MONITORING DIAGRAM B

ZACHRY ENGINEERING CENTER

AIR HANDLING UNIT 10

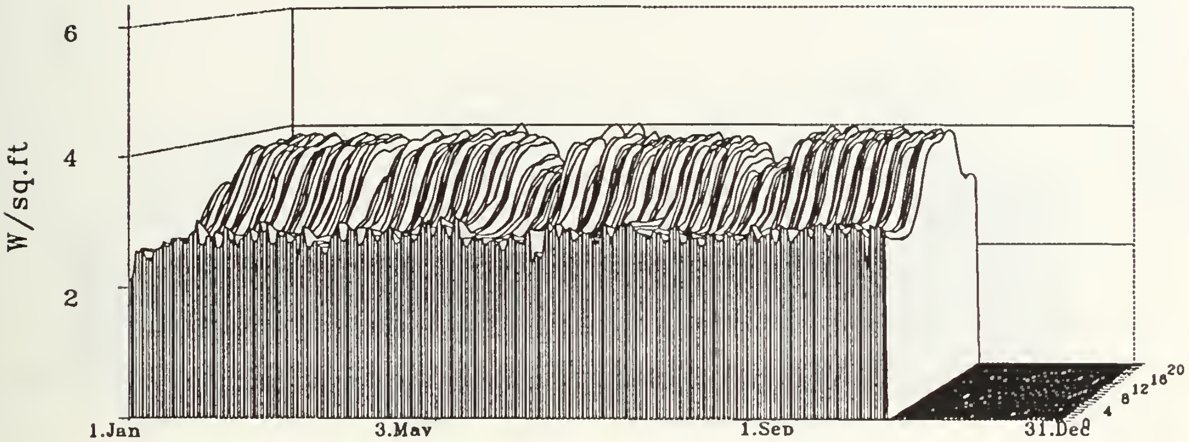


Tab D-3

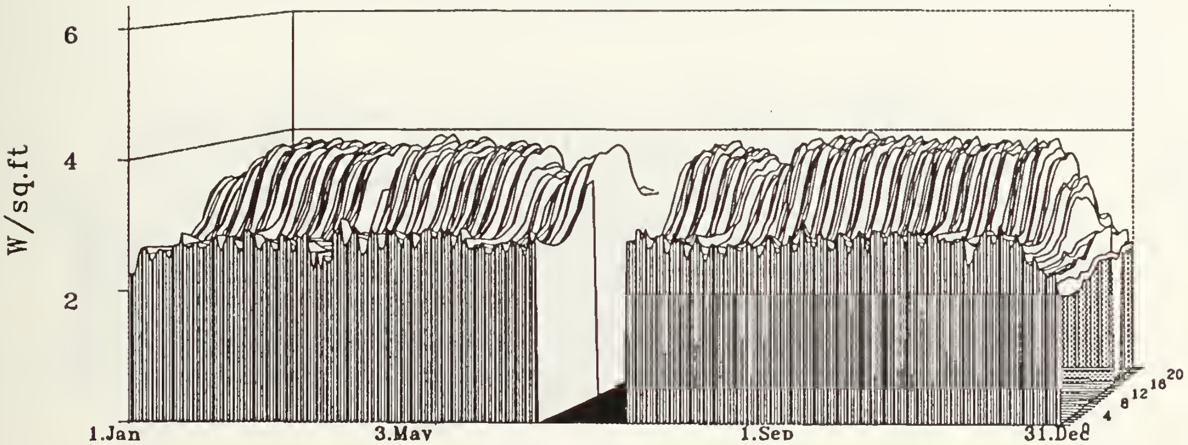
3-D Surface Plots

Zachry Engineering Center (ZEC)
W.B. Electric as W/sq.ft.

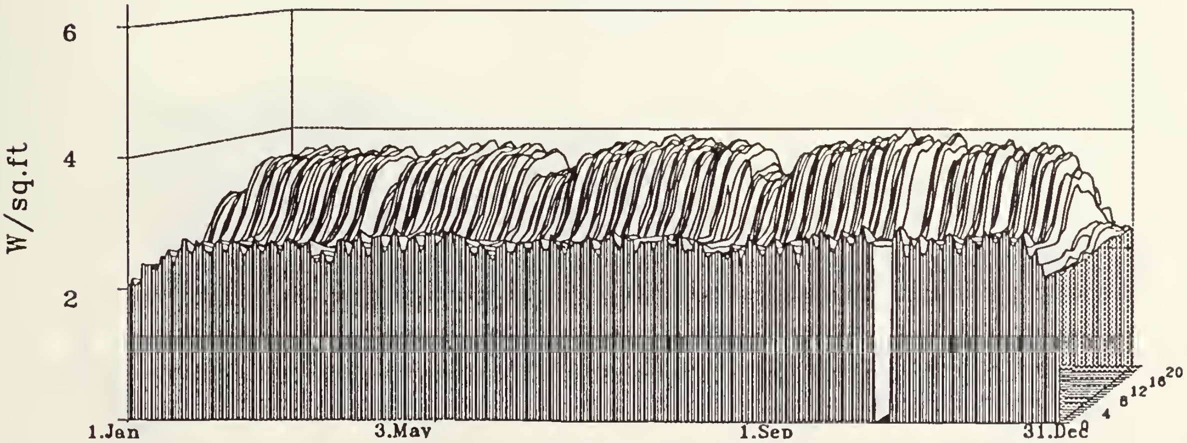
1994



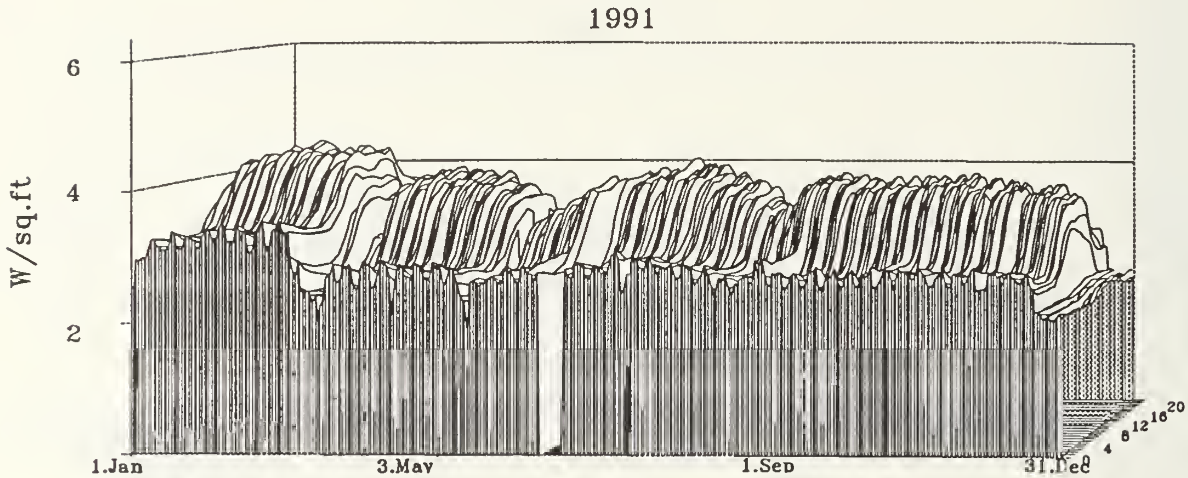
1993

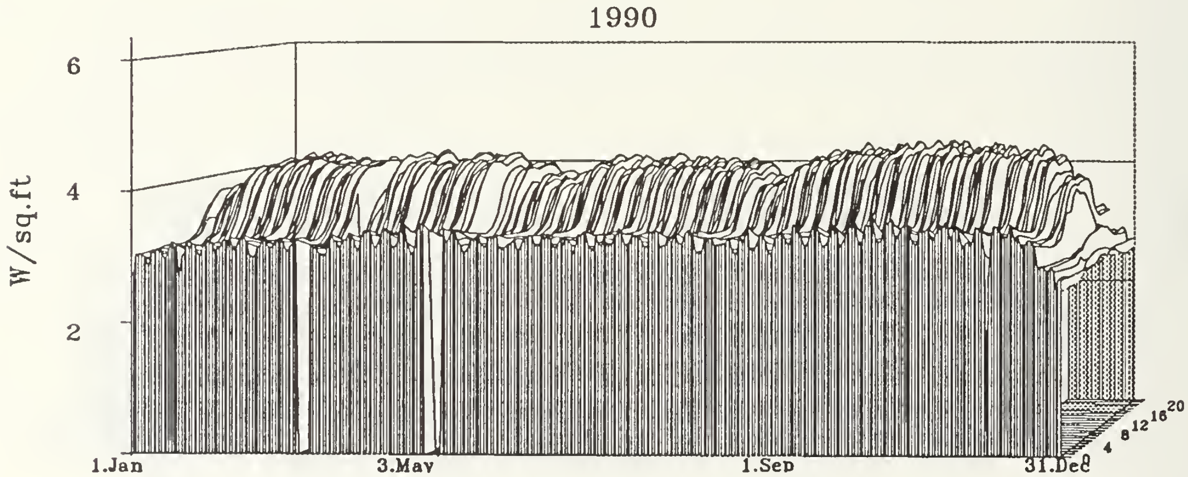


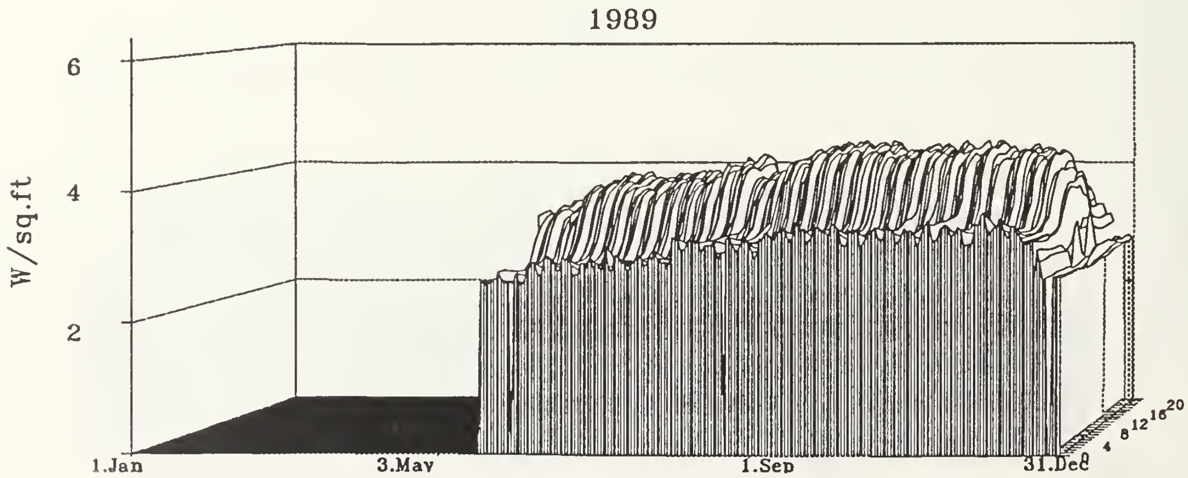
1992



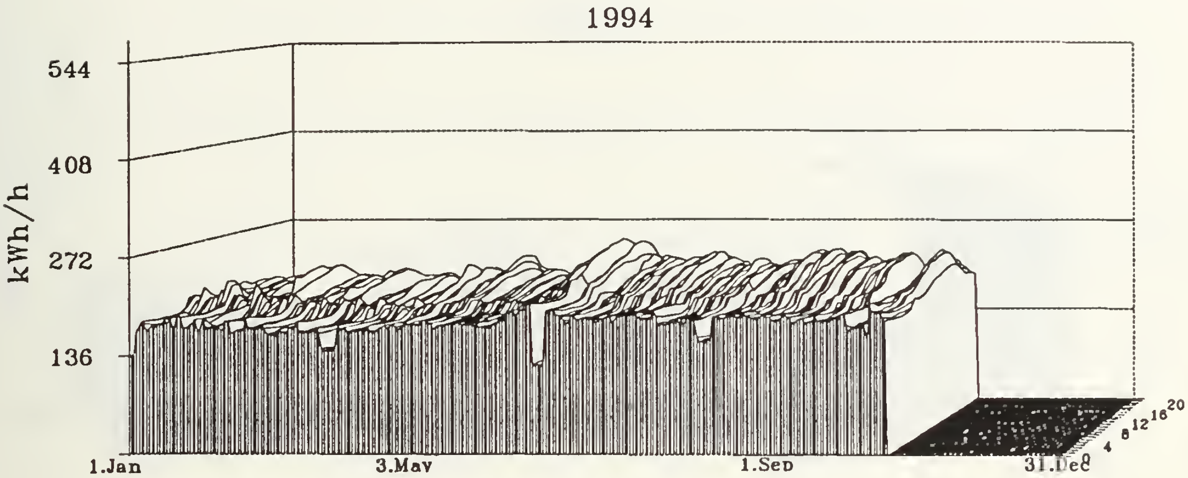
Zachry Engineering Center (ZEC)
W.B. Electric as W/sq.ft.

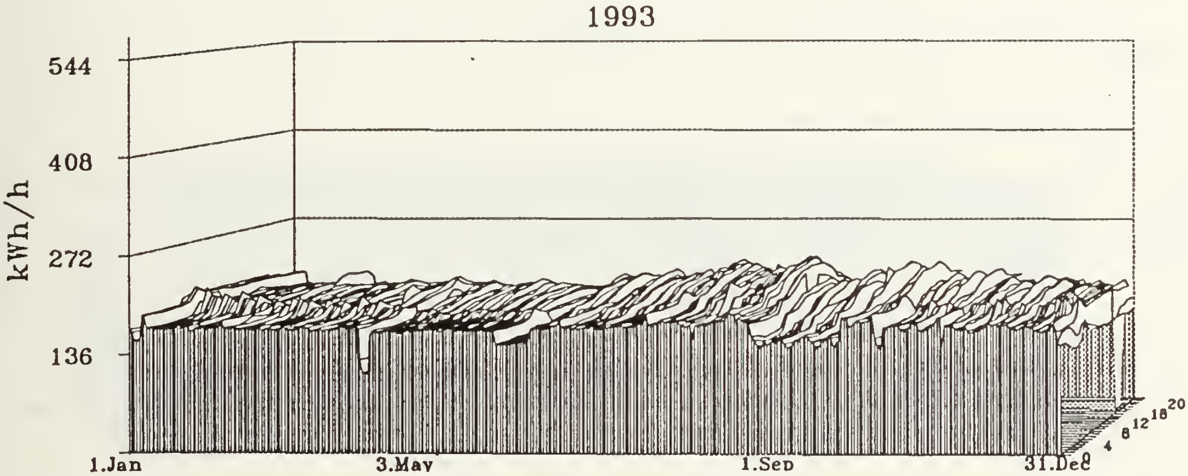


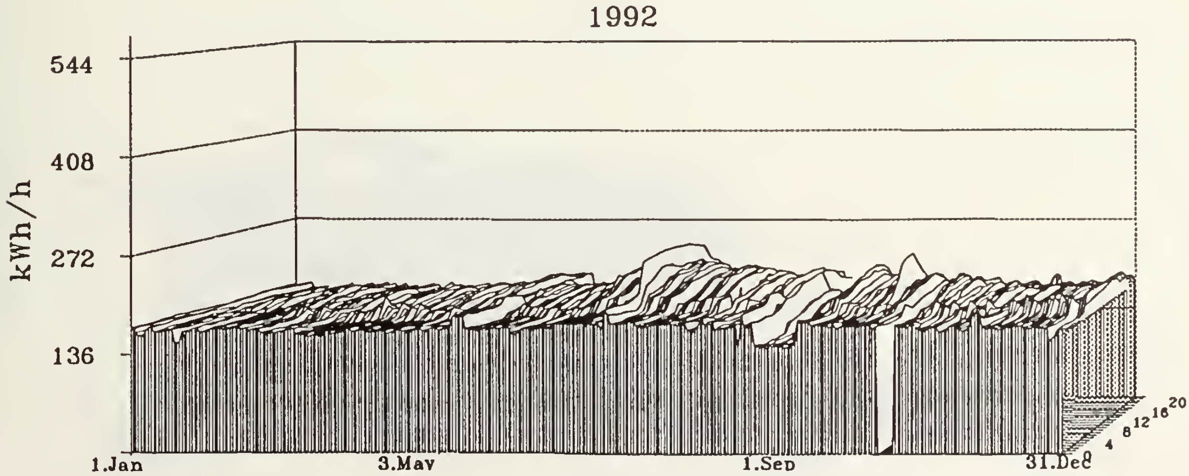




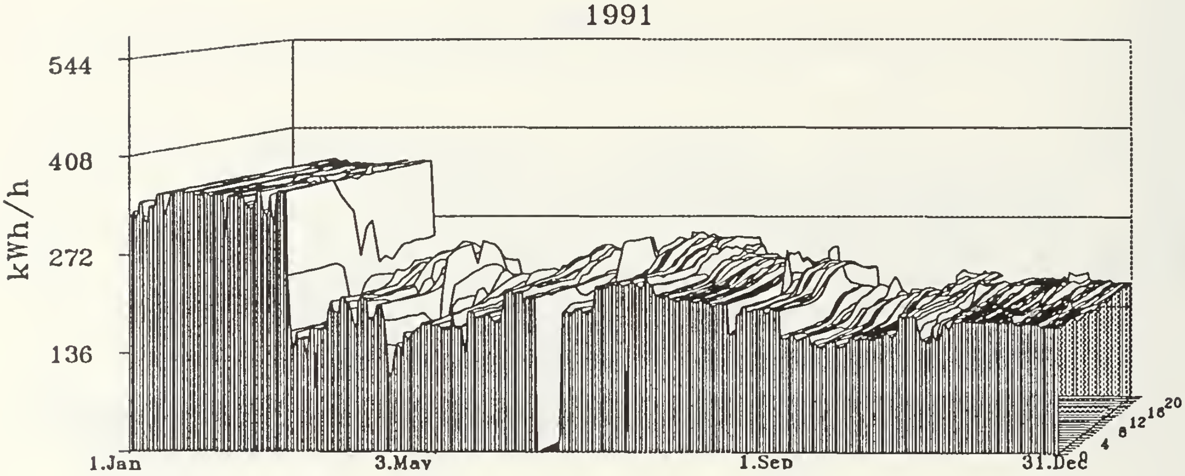
Zachry Engineering Center (ZEC)
Motor Control Cen. (kWh/h)

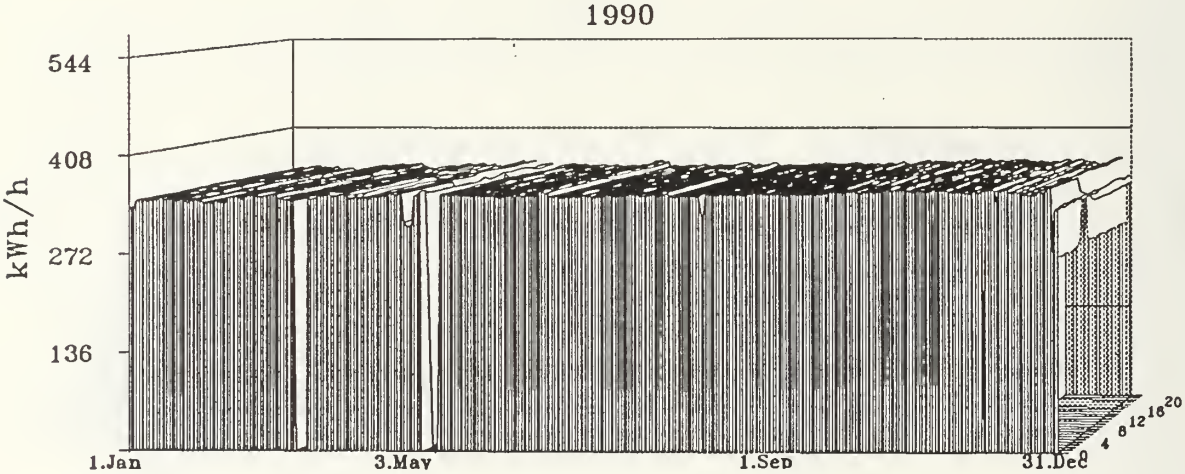


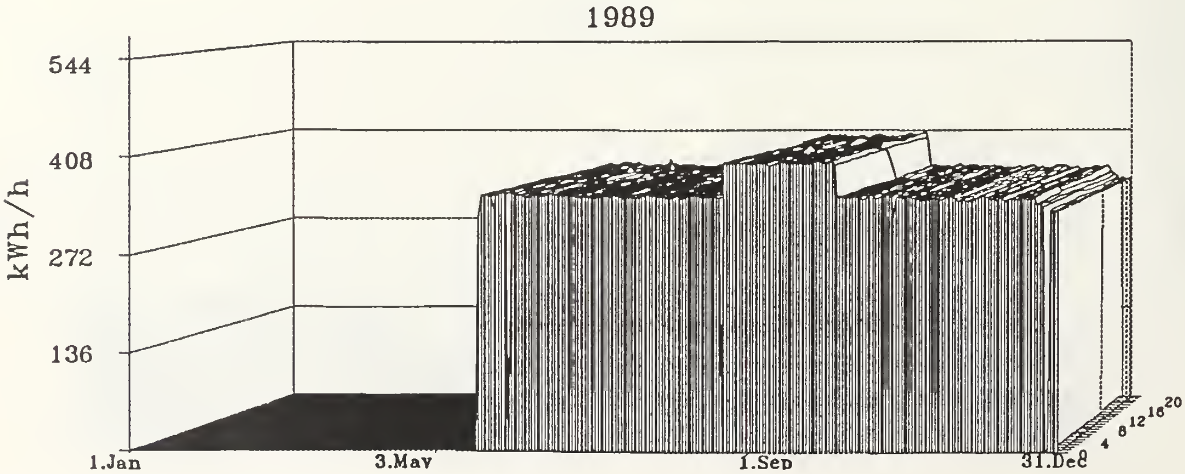




Zachry Engineering Center (ZEC)
Motor Control Cen. (kWh/h)

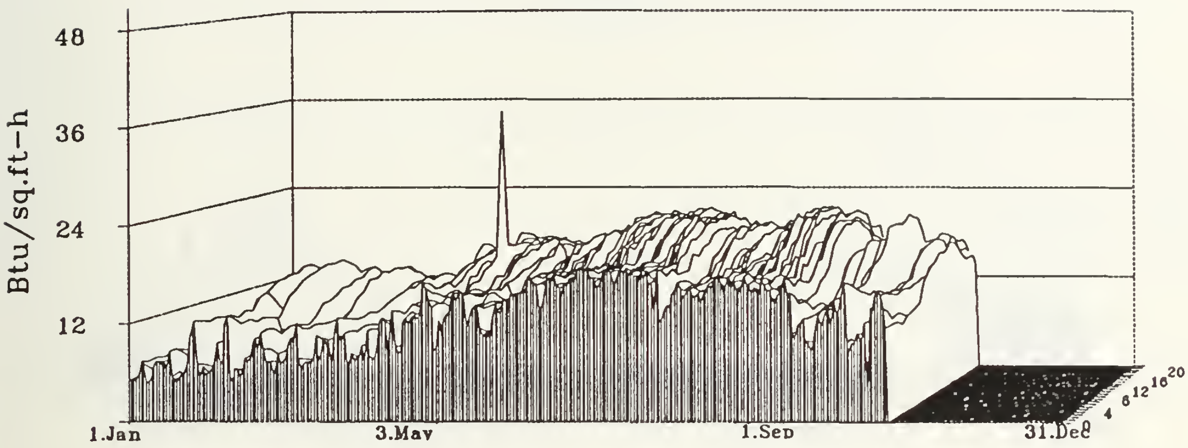




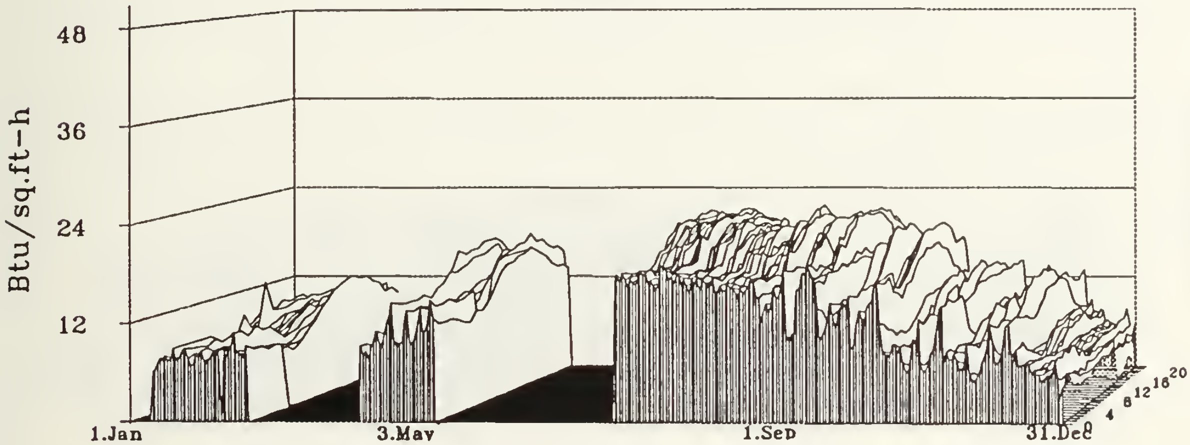


Zachry Engineering Center (ZEC)
W.B. CHW as Btu/sq.ft.-h

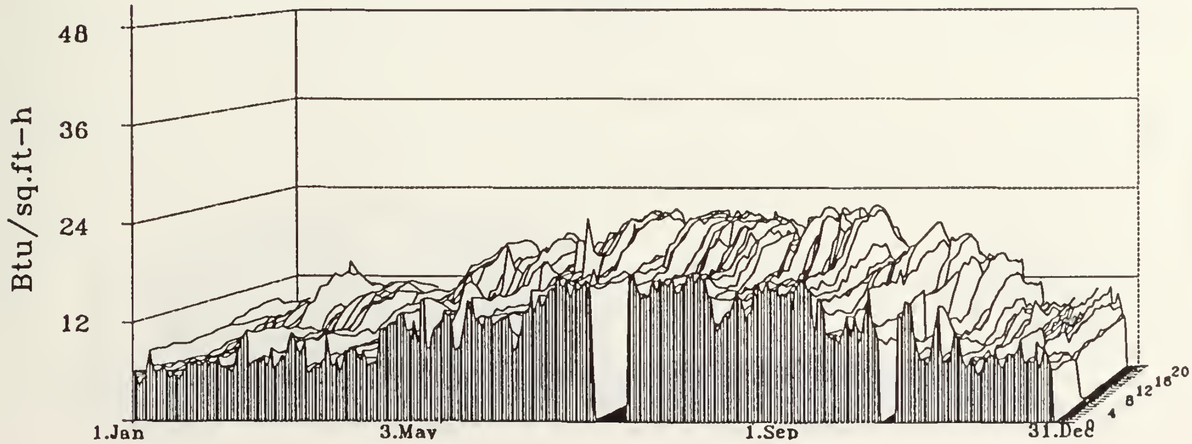
1994



1993

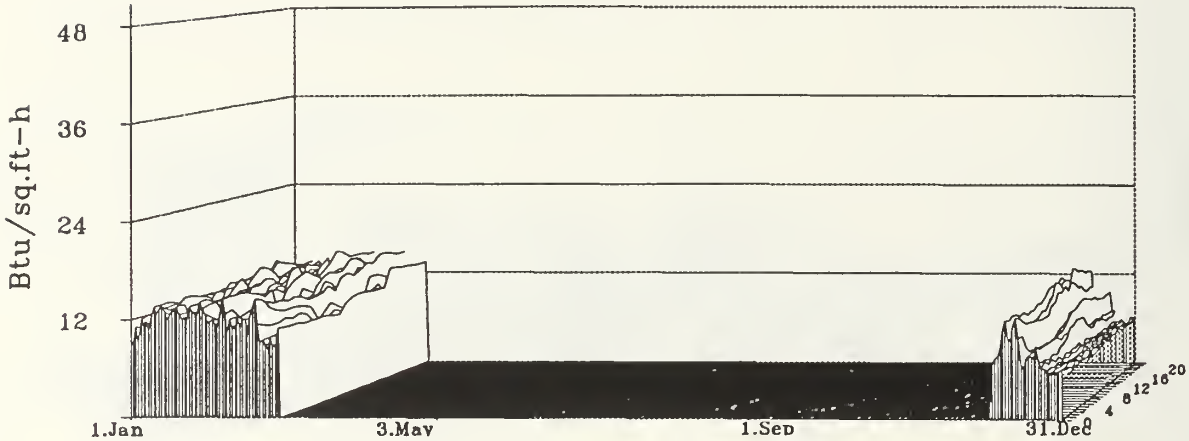


1992

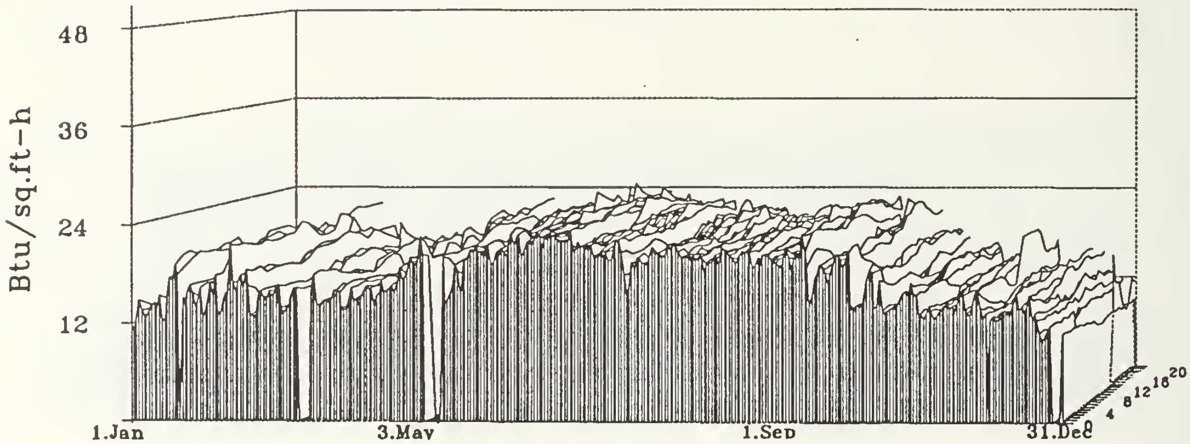


Zachry Engineering Center (ZEC)
W.B. CHW as Btu/sq.ft.-h

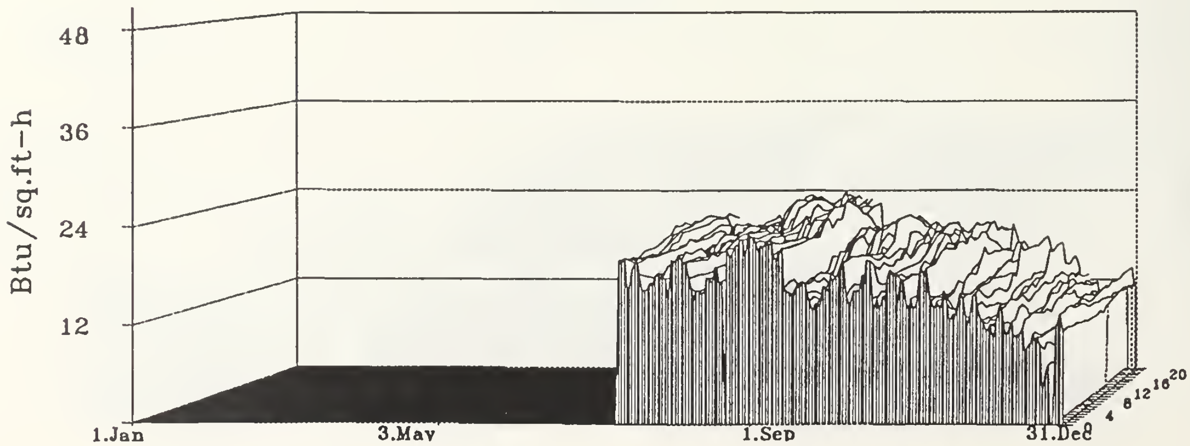
1991



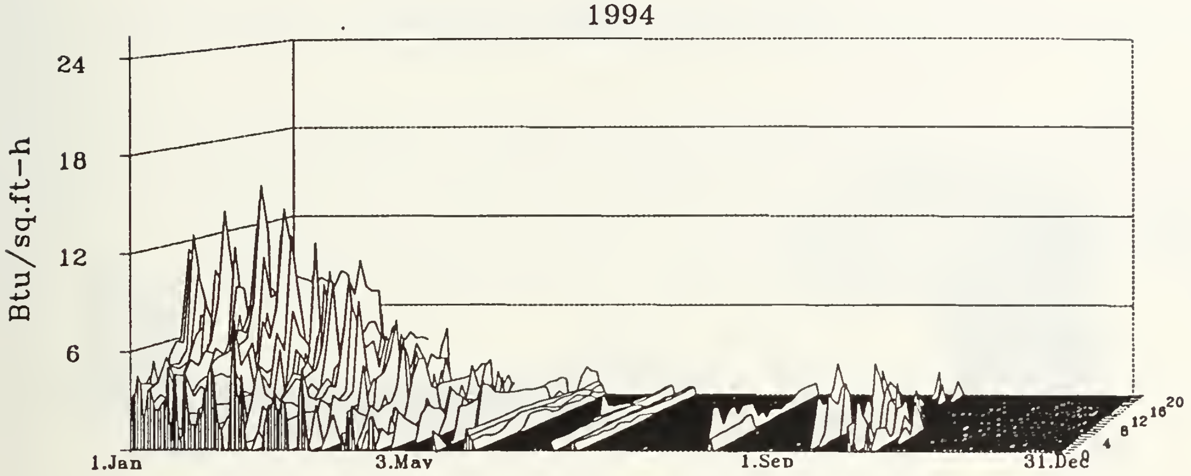
1990

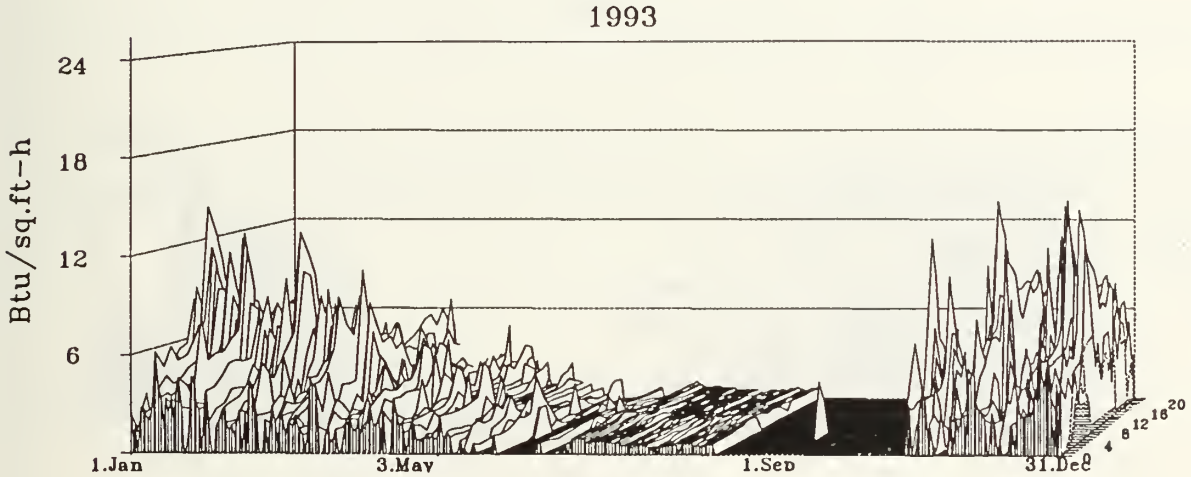


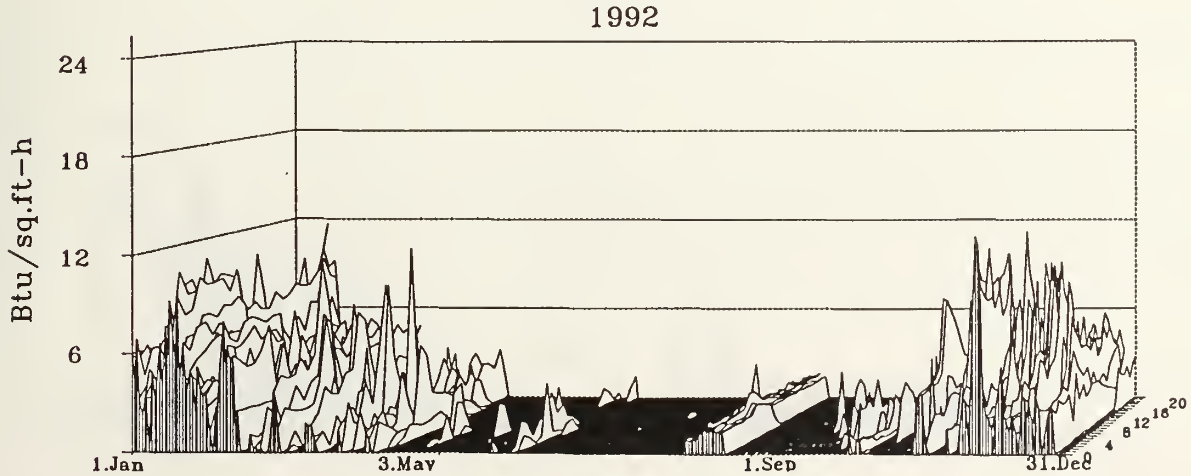
1989



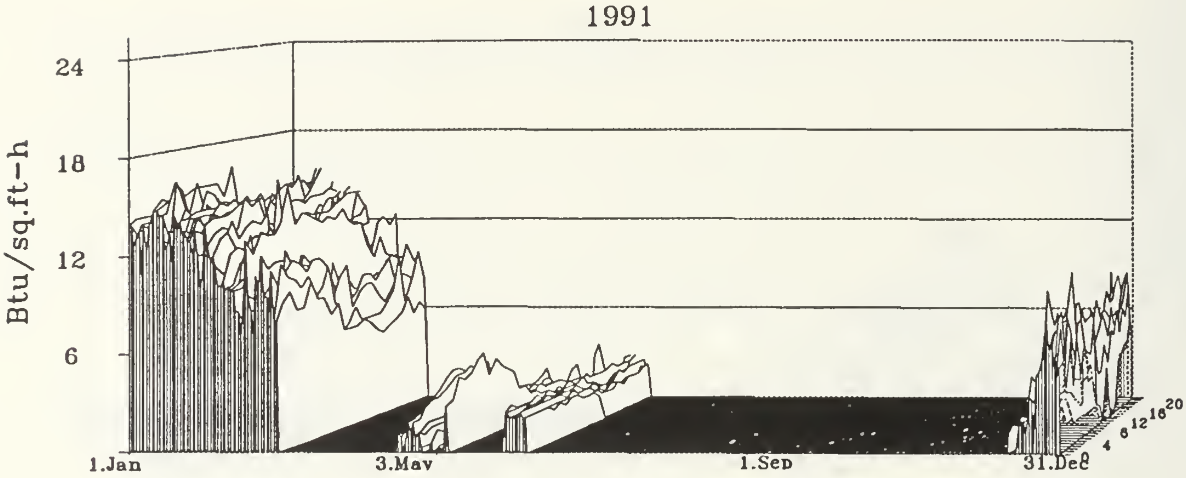
Zachry Engineering Center (ZEC)
W.B. HW as Btu/sq.ft.-h

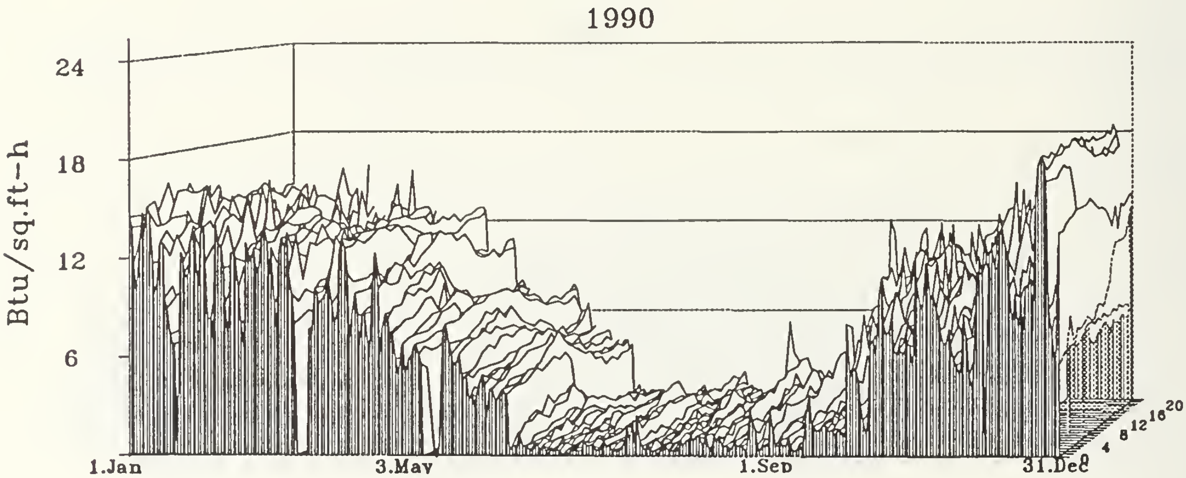


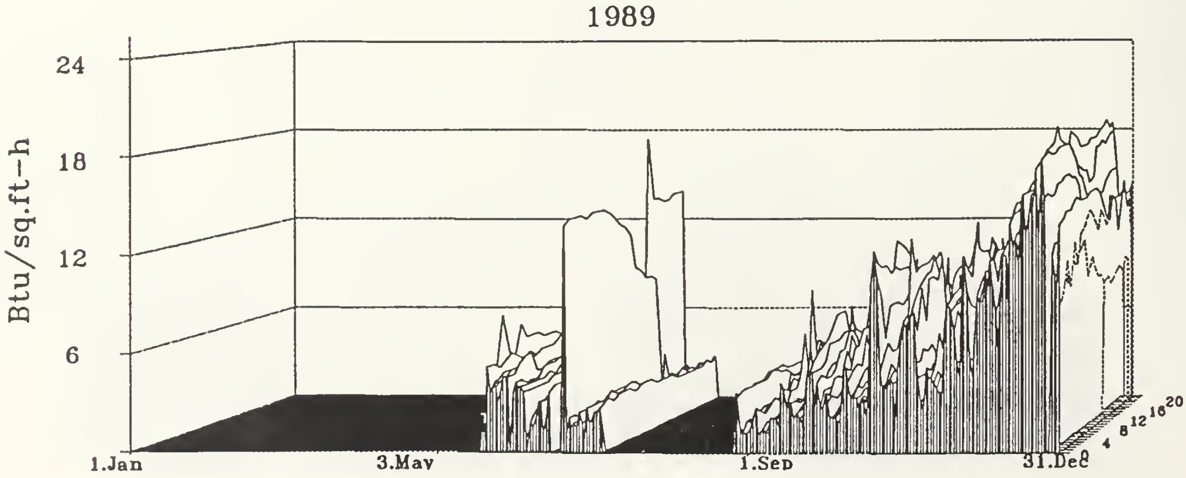




Zachry Engineering Center (ZEC)
W.B. HW as Btu/sq.ft.-h



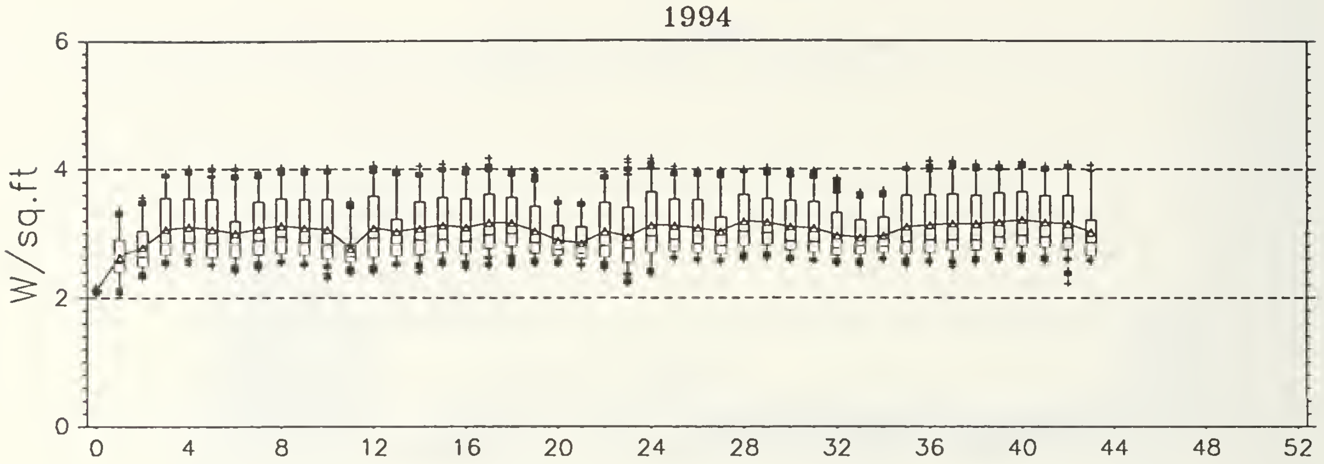


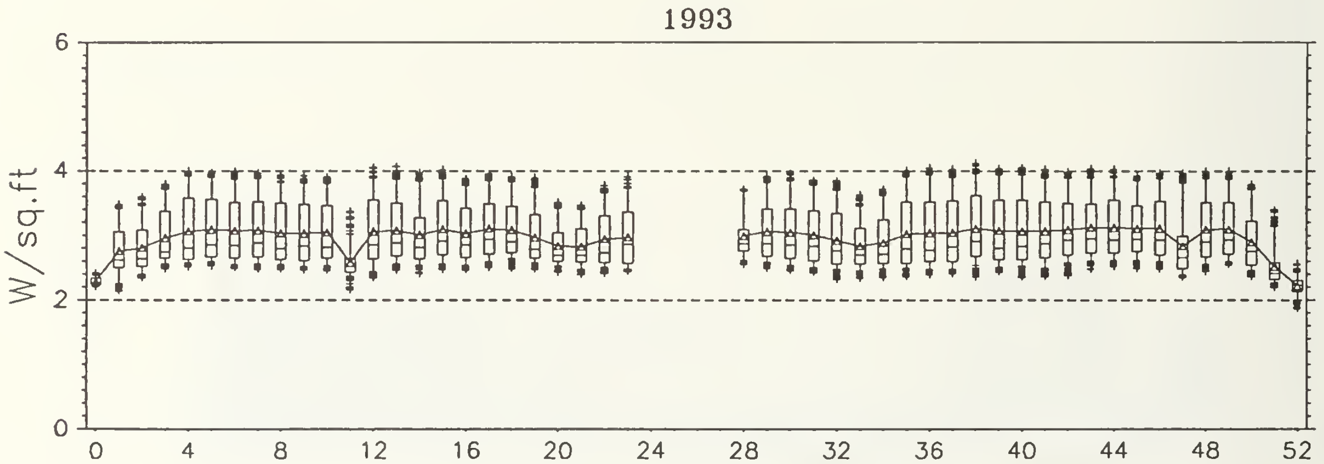


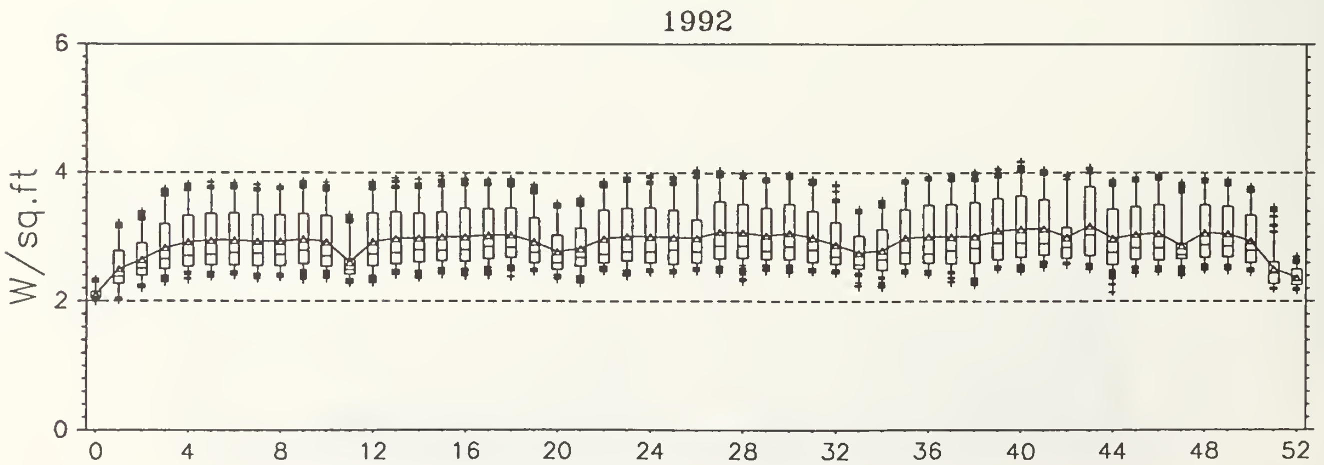
Tab D-4

Weekly Box Whisker Mean Plots

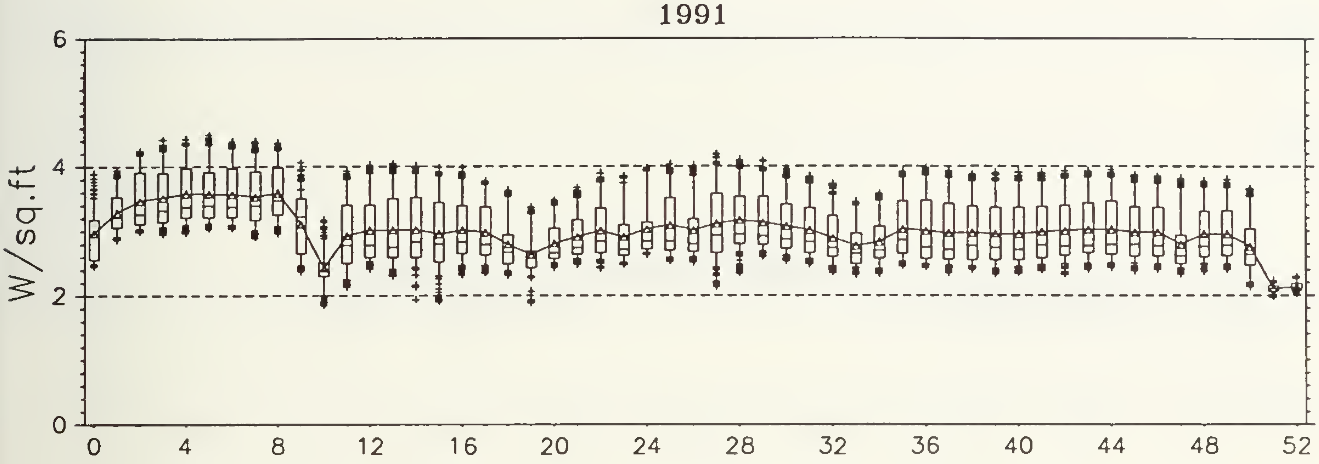
Zachry Engineering Center (ZEC)
W.B. Electric as W/sq.ft.

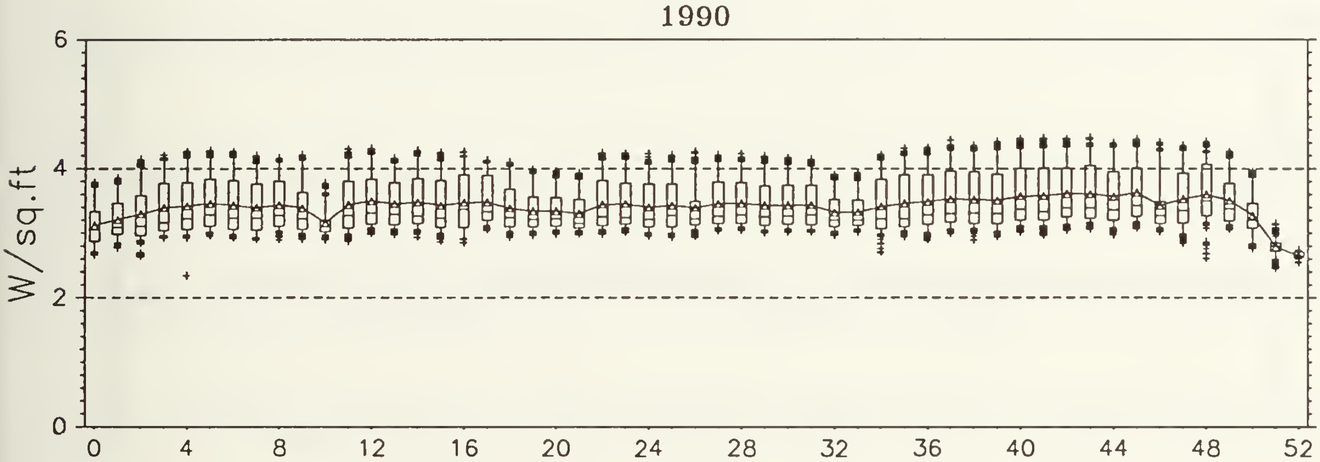


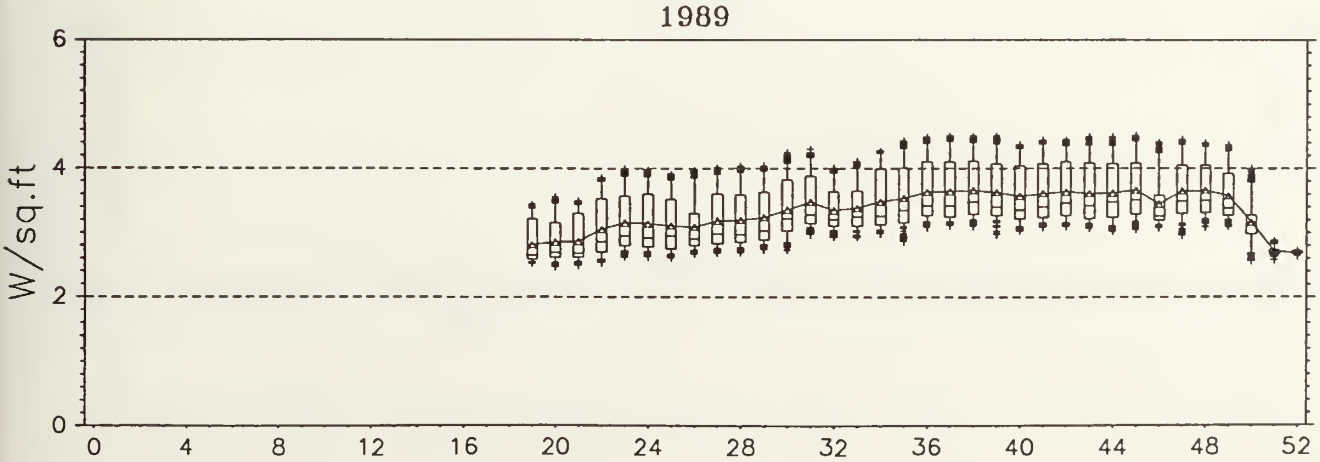




Zachry Engineering Center (ZEC)
W.B. Electric as W/sq.ft.

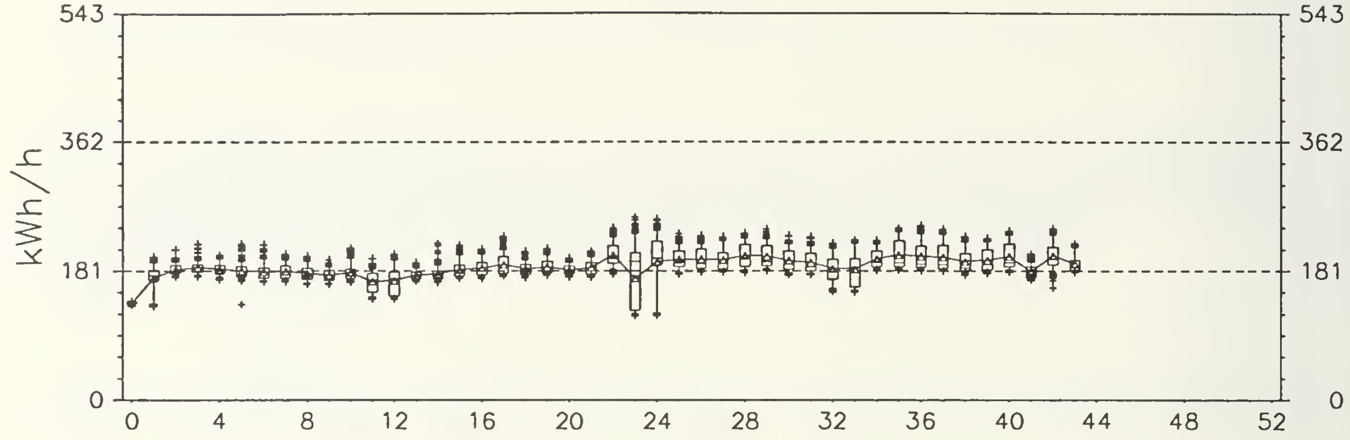




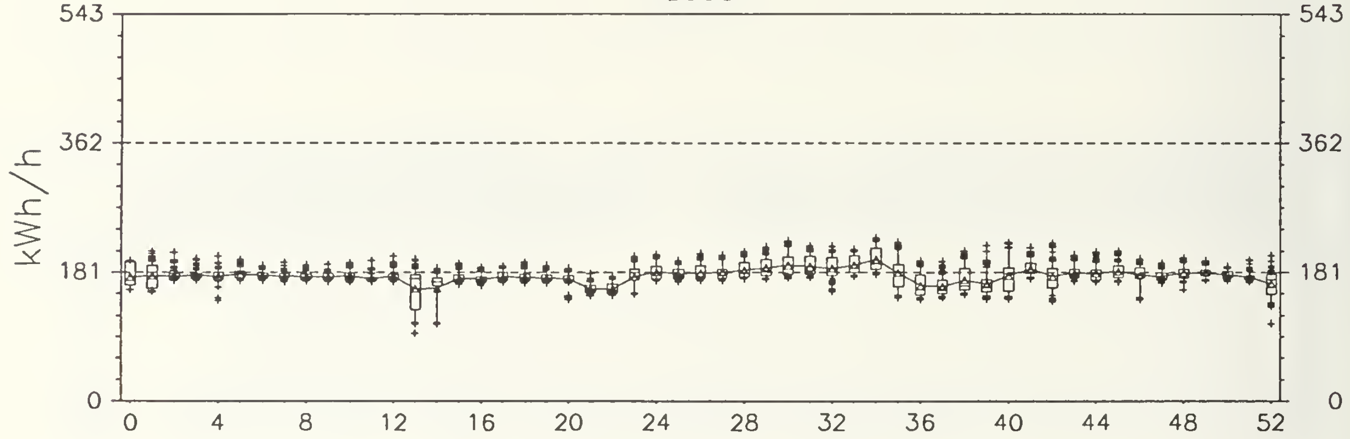


Zachry Engineering Center (ZEC)
Motor Control Cen. (kWh/h)

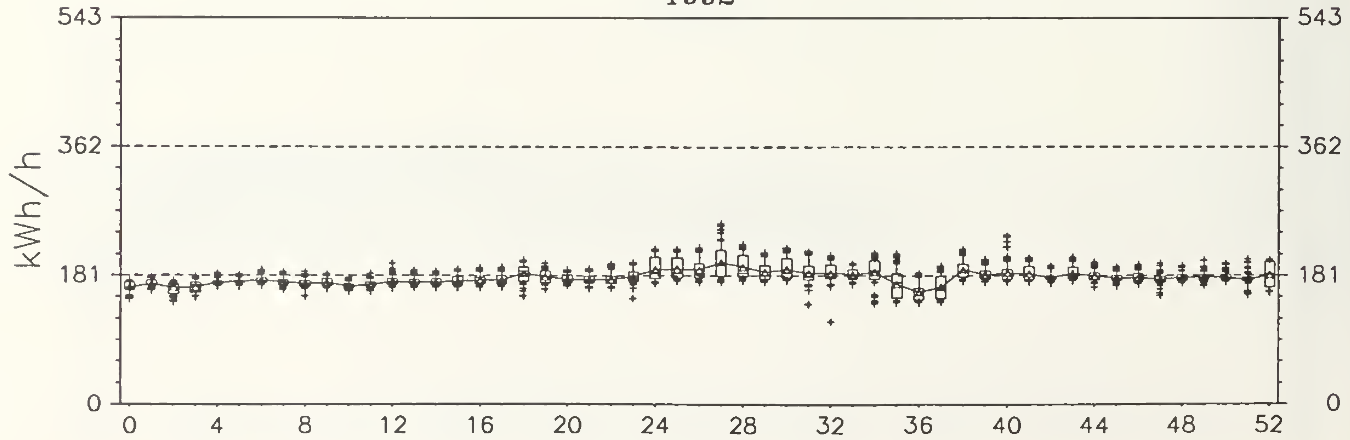
1994



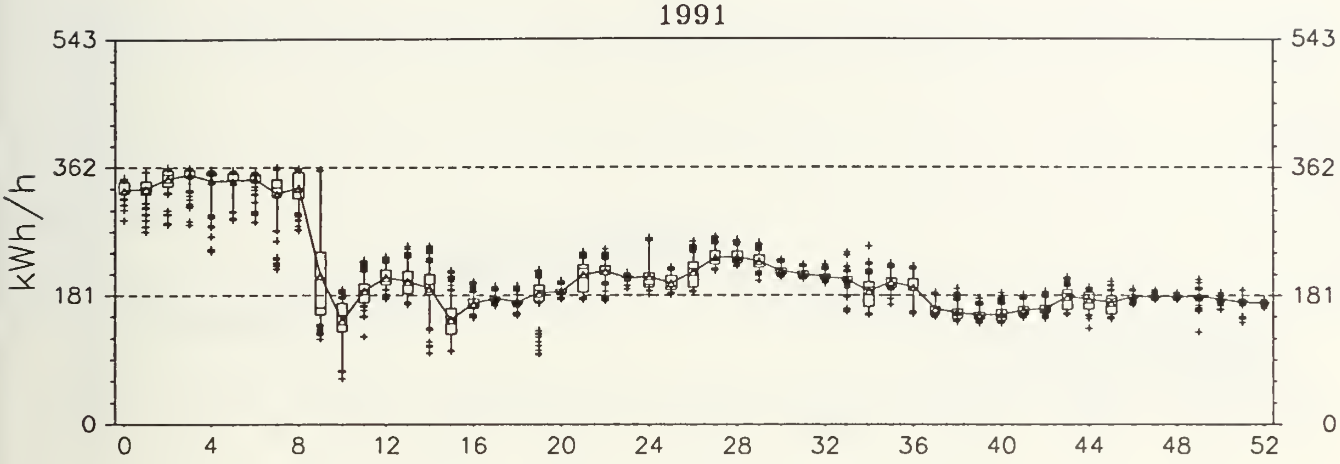
1993

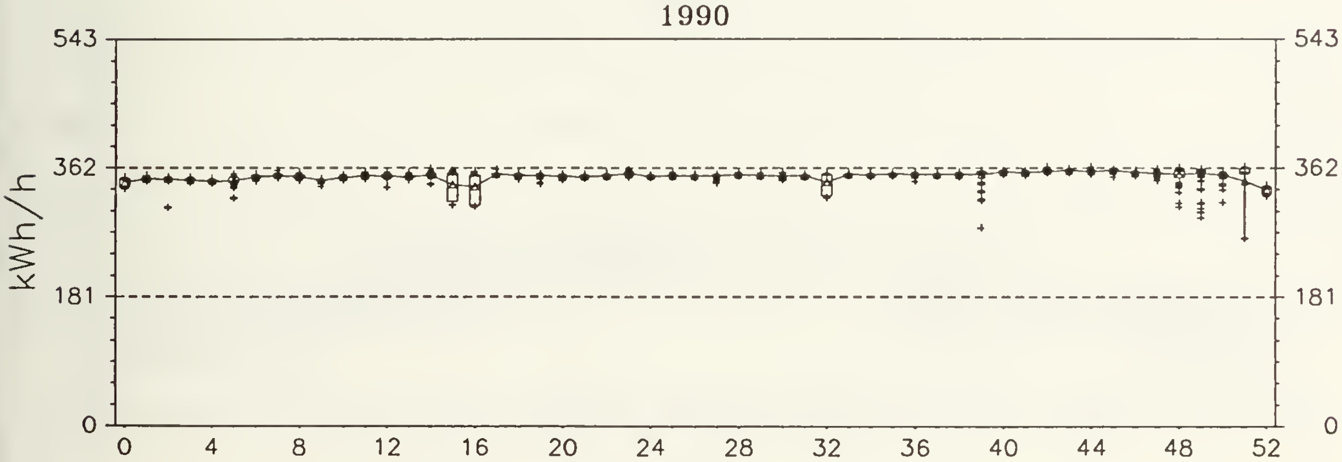


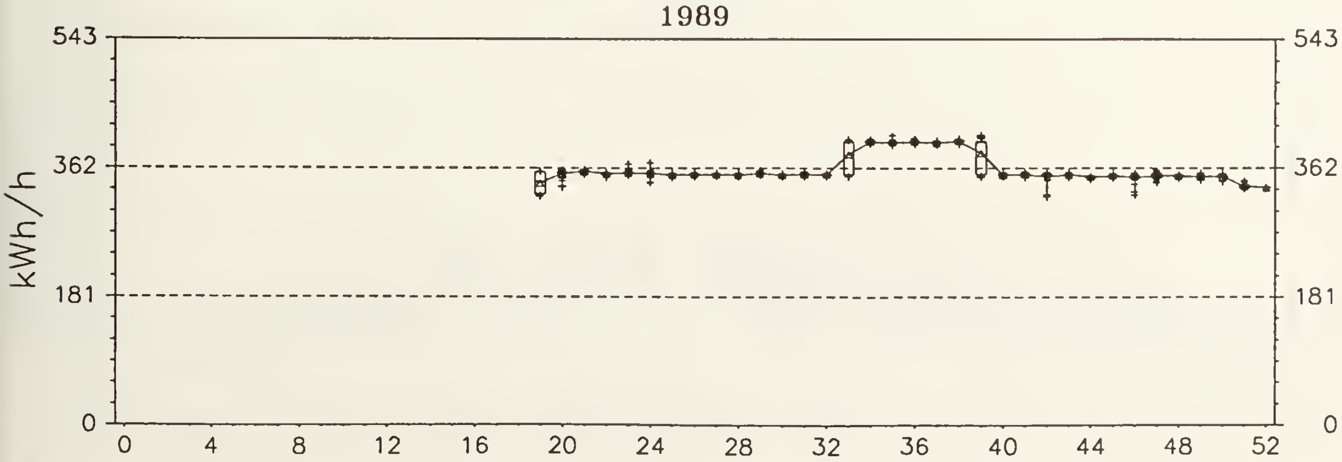
1992



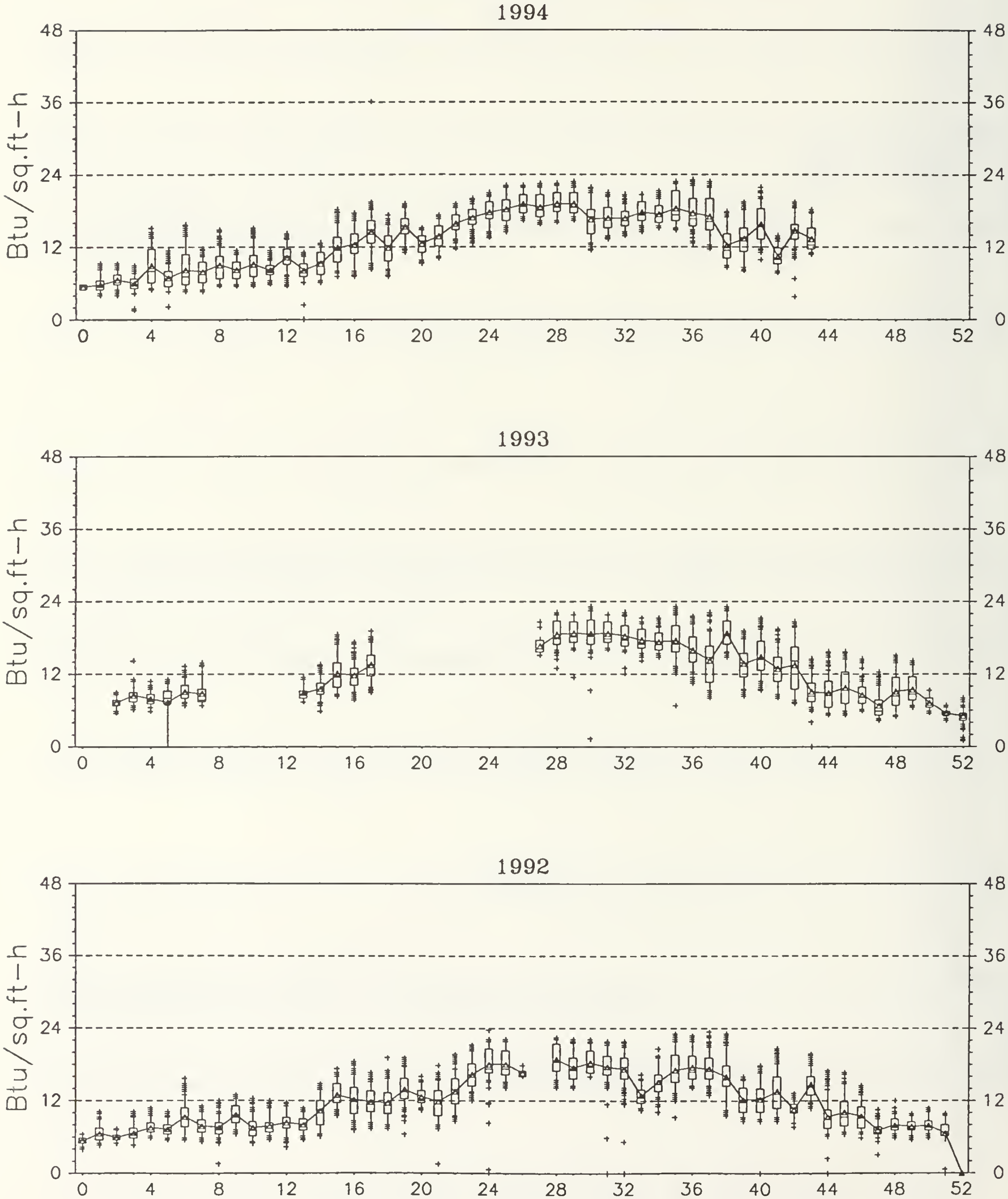
Zachry Engineering Center (ZEC)
Motor Control Cen. (kWh/h)



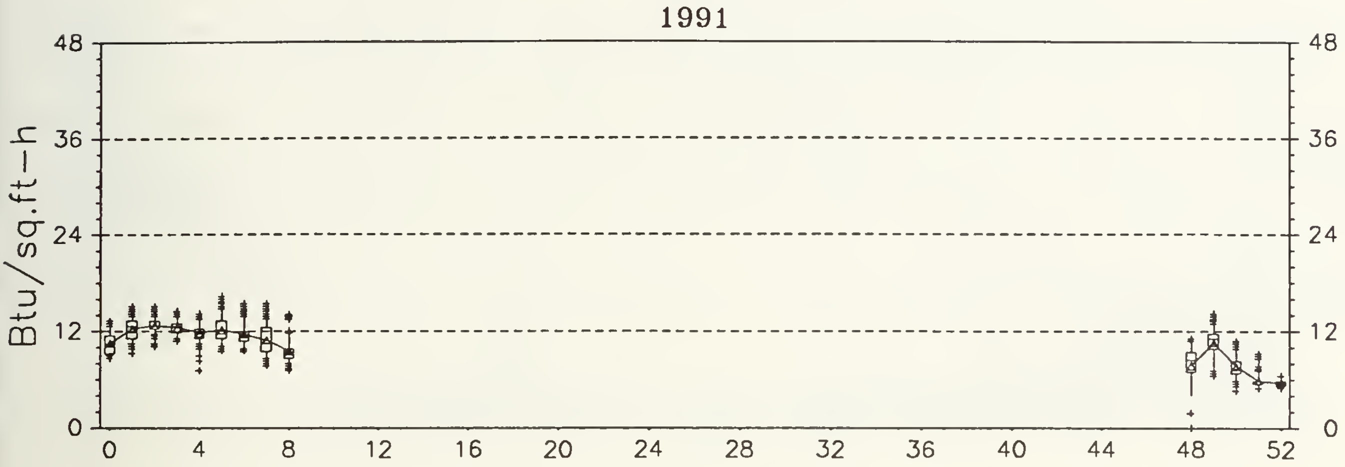


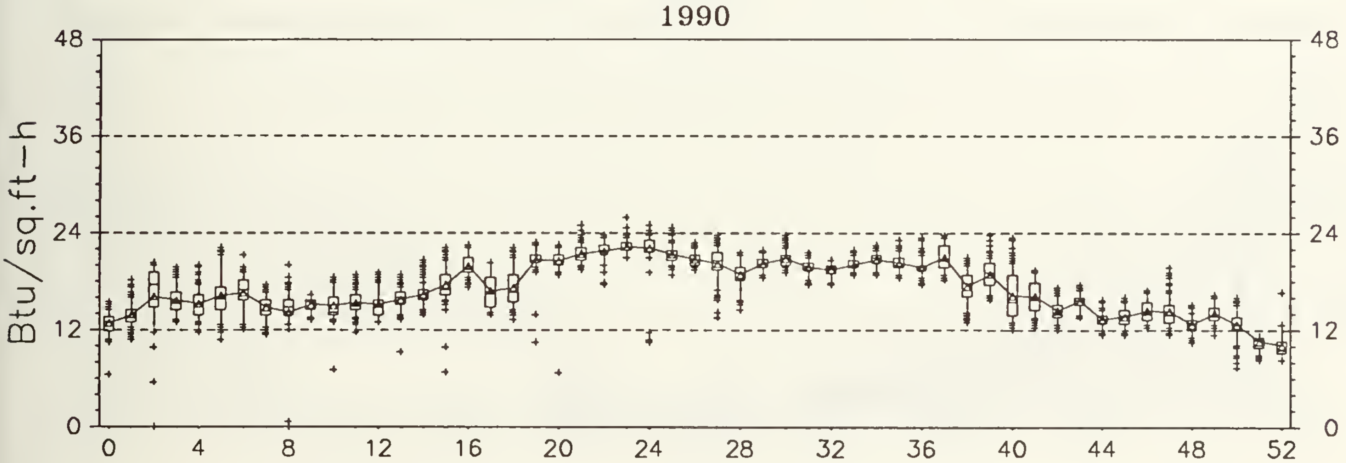


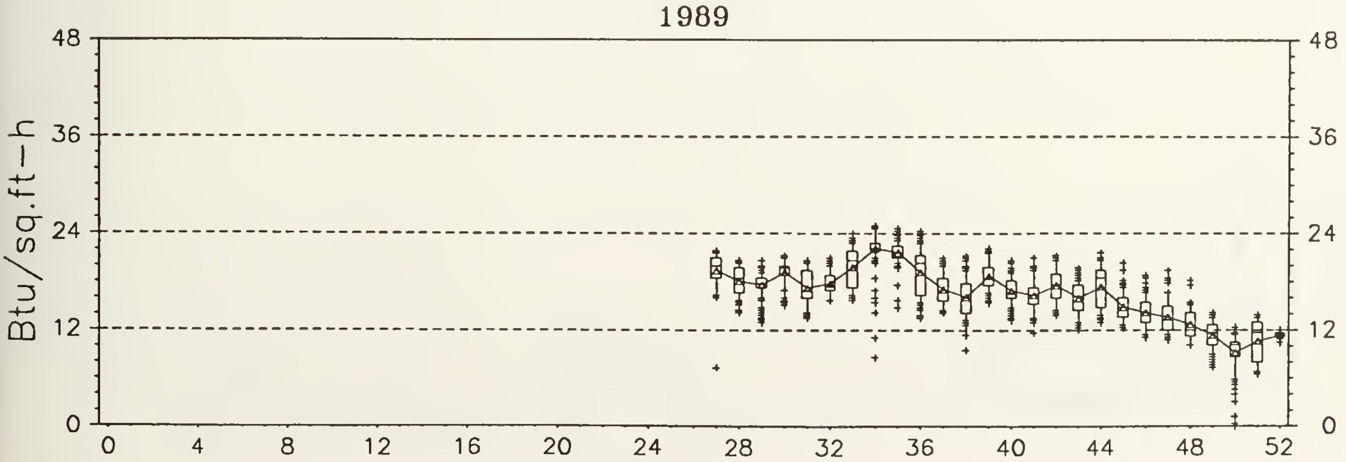
Zachry Engineering Center (ZEC)
W.B. CHW as Btu/sq.ft.-h



Zachry Engineering Center (ZEC)
W.B. CHW as Btu/sq.ft.-h

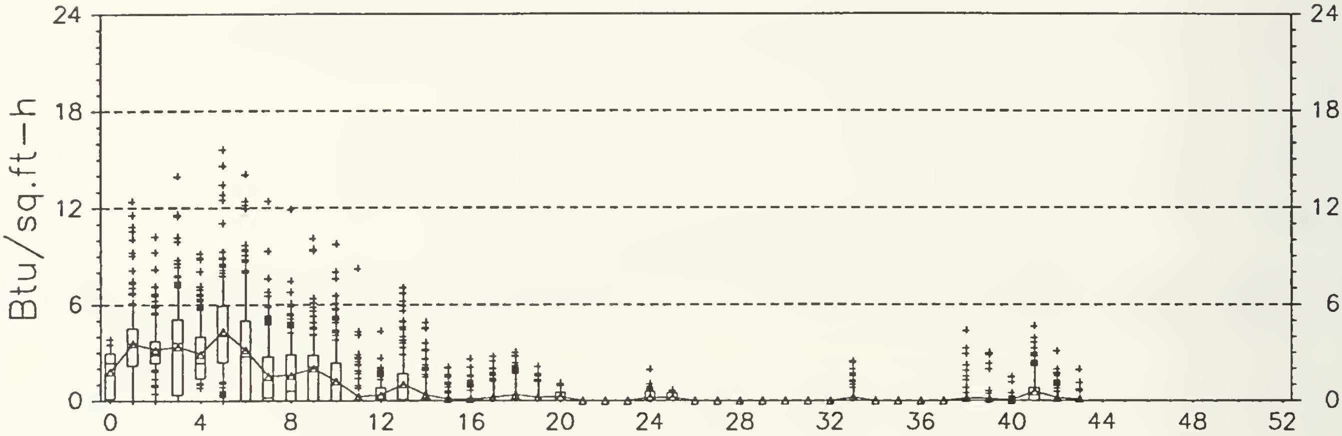




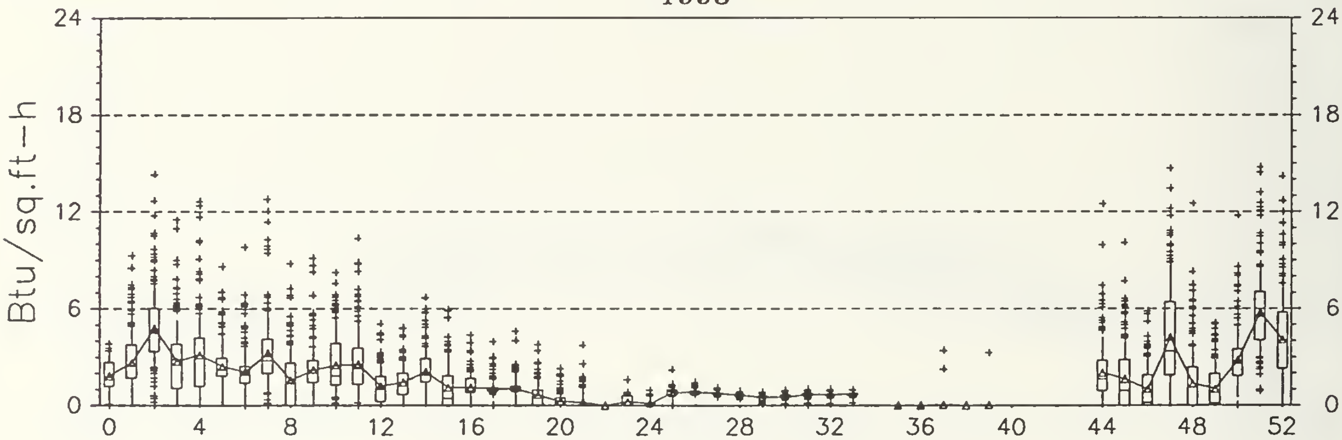


Zachry Engineering Center (ZEC)
W.B. HW as Btu/sq.ft.-h

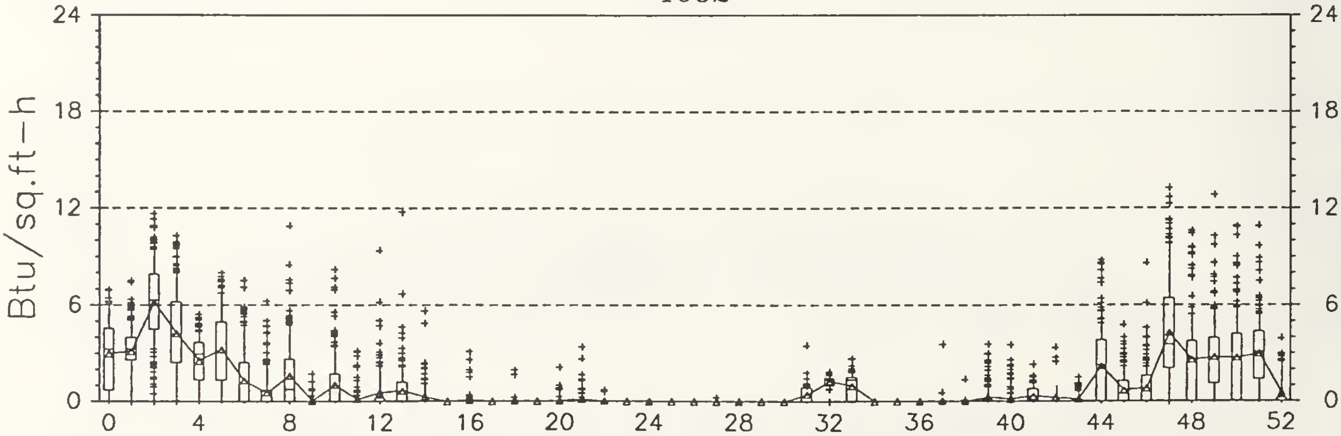
1994



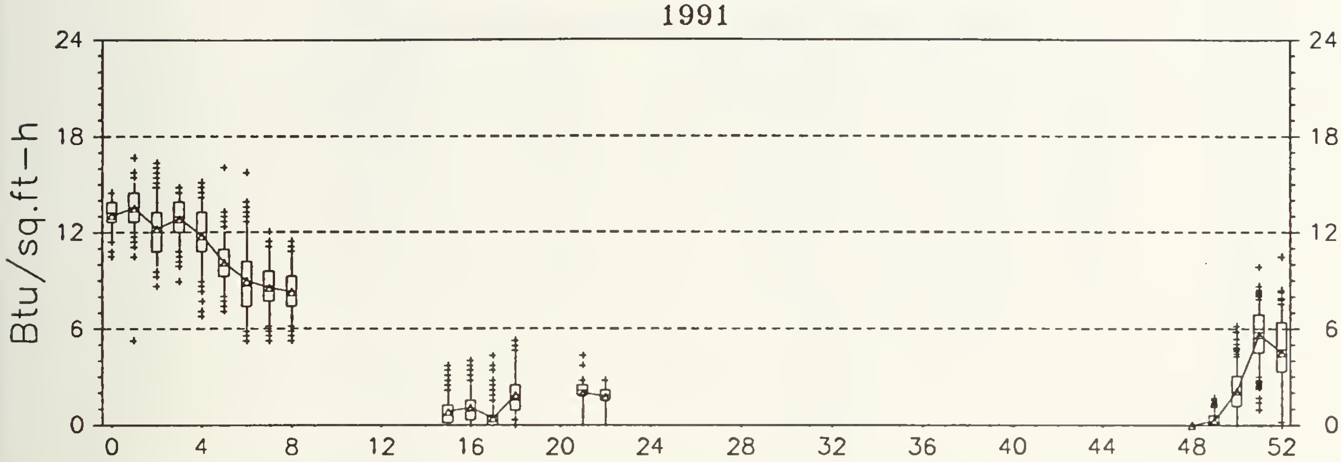
1993

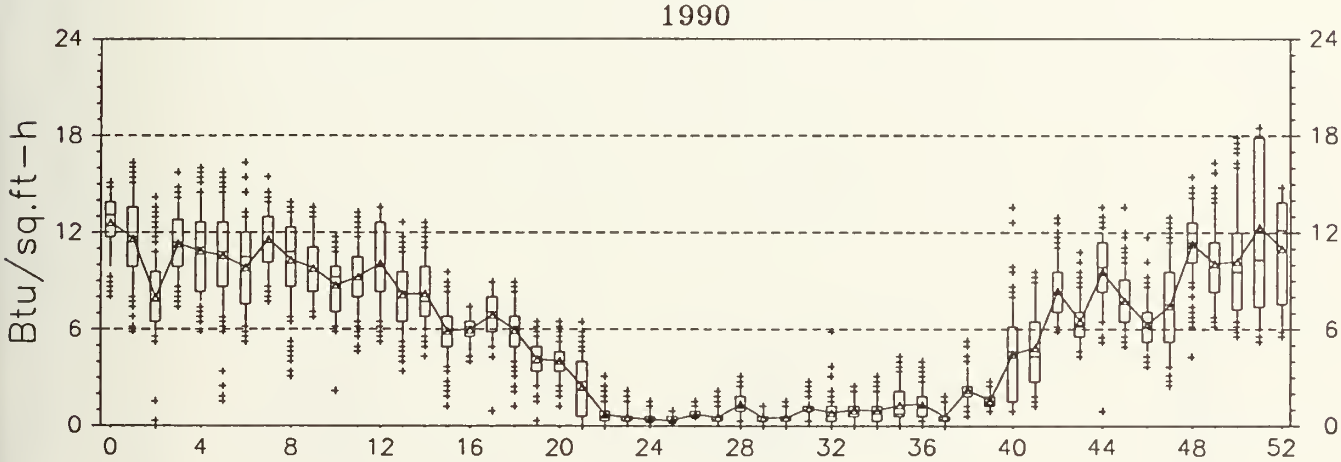


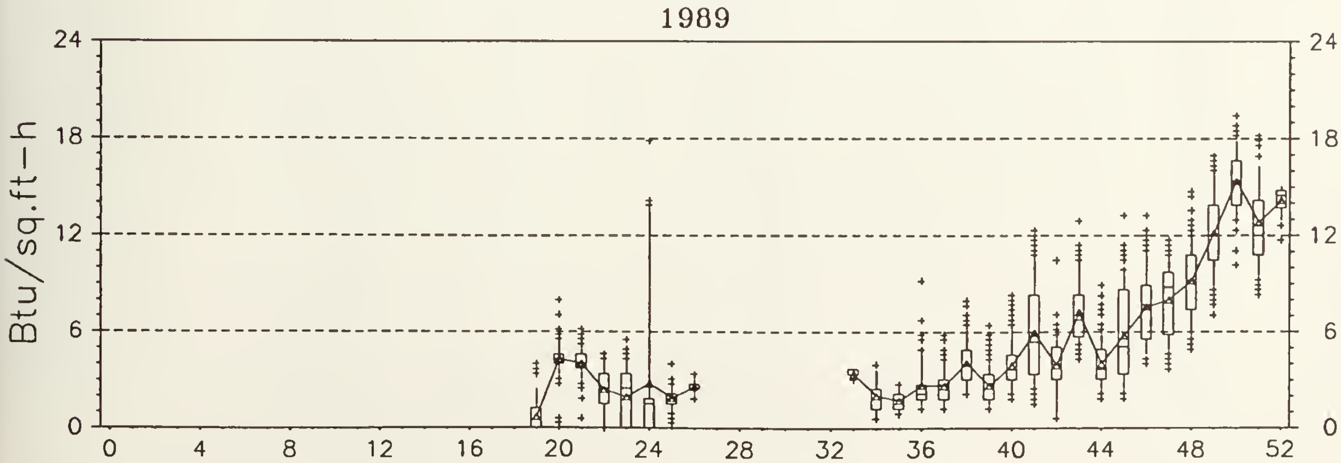
1992



Zachry Engineering Center (ZEC)
W.B. HW as Btu/sq.ft.-h



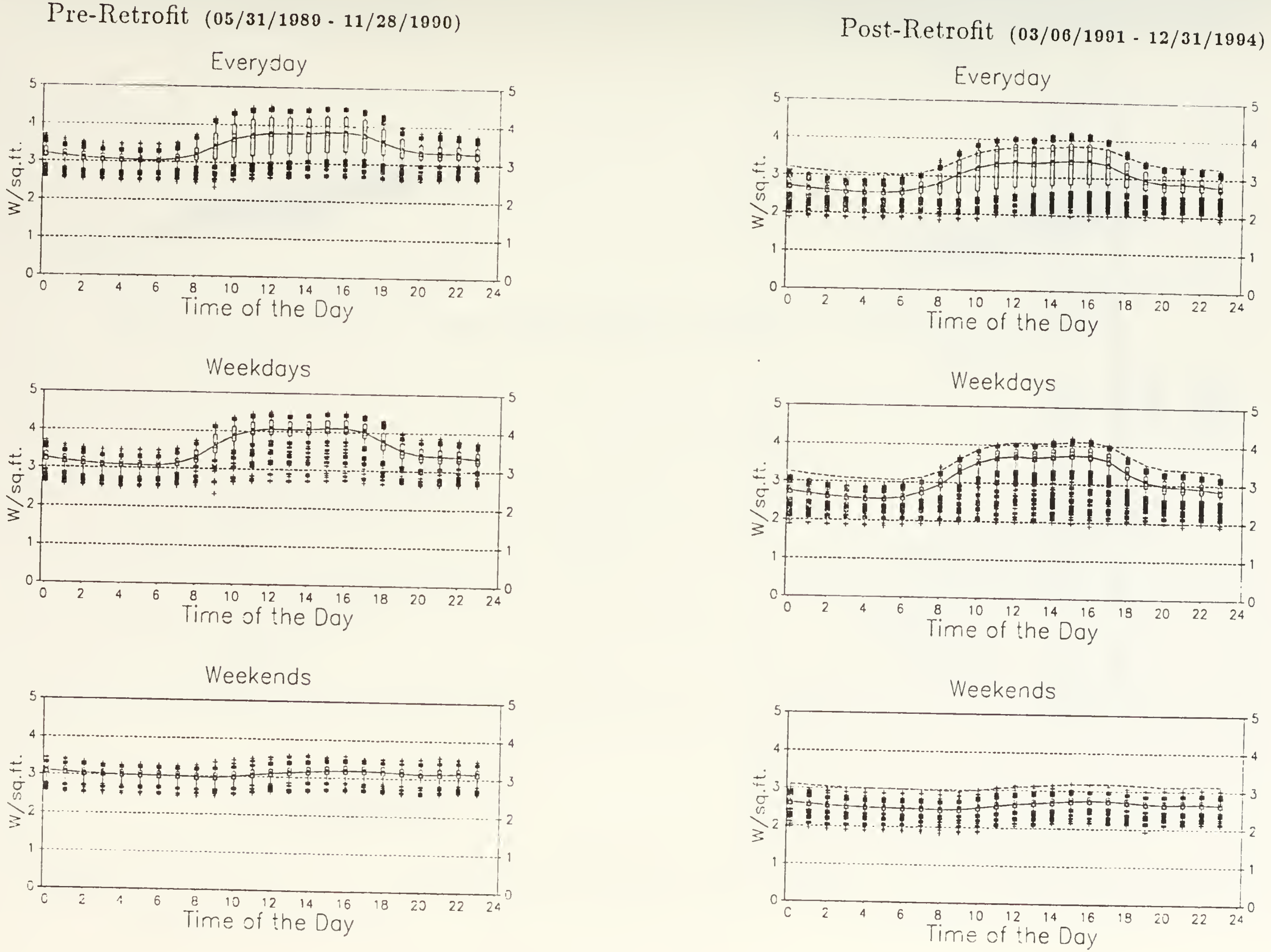




Tab D-5

Pre/Post, Weekday/Weekend, 24 Hour BWM Plots

Zachry Engineering Center (ZEC)
W.B. Electric as W/sq.ft.



Tab D-6

Tab D-6

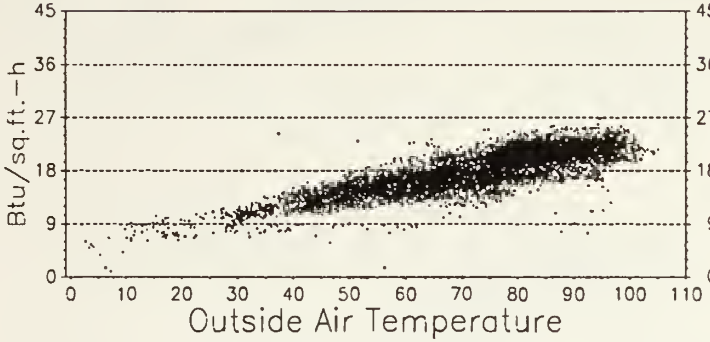
Pre/Post, Weekday/Weekend, BWM Temperature Binned Plots

Pre/Post, Weekday/Weekend, BWM Temperature Binned Plots

Zachry Engineering Center (ZEC)
W.B. CHW as Btu/sq.ft.-h

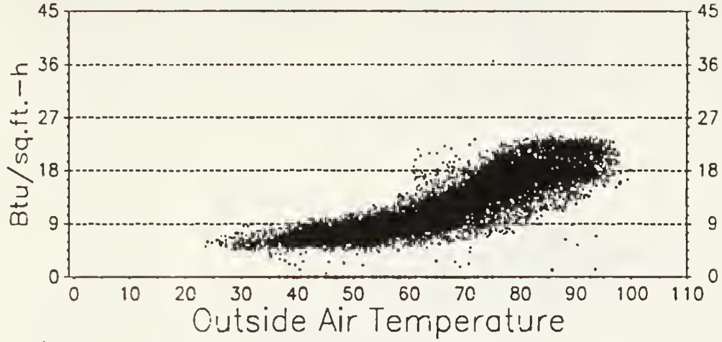
Pre-Retrofit (05/31/1989 - 11/28/1990)

Everyday



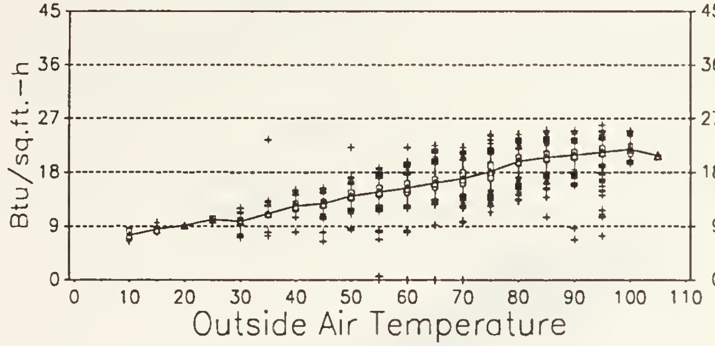
Post-Retrofit (03/06/1991 - 12/31/1994)

Everyday

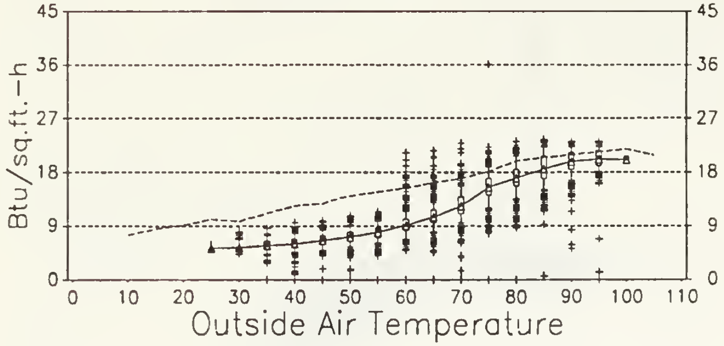


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

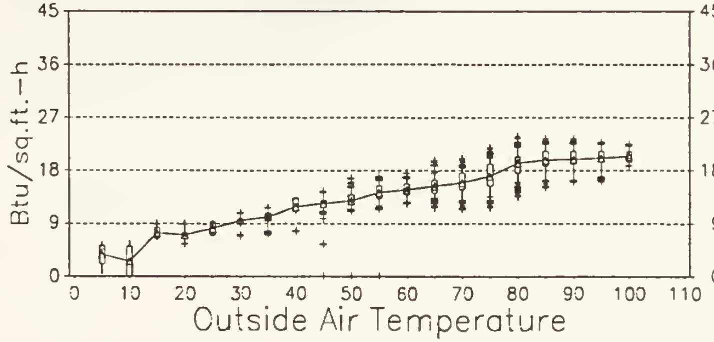
Weekdays



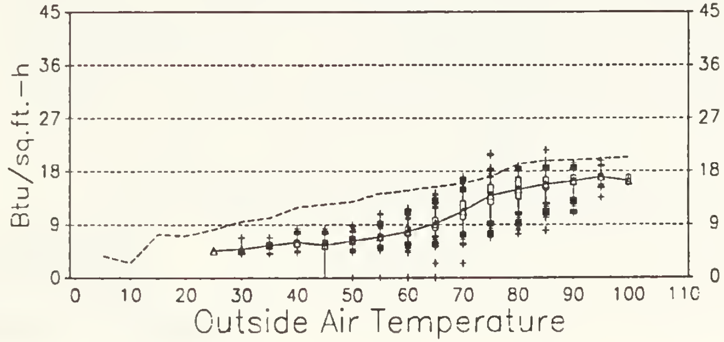
Weekdays



Weekends



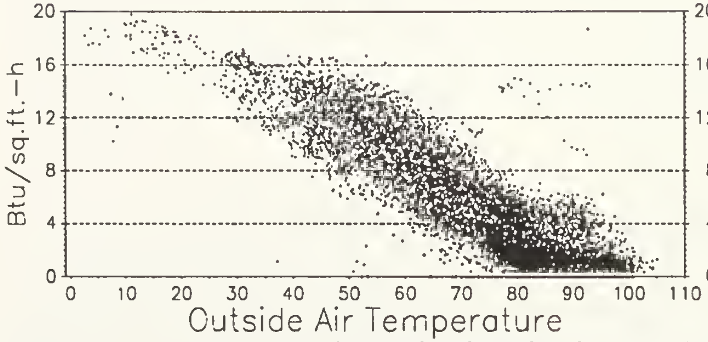
Weekends



Zachry Engineering Center (ZEC)
W.B. HW as Btu/sq.ft.-h

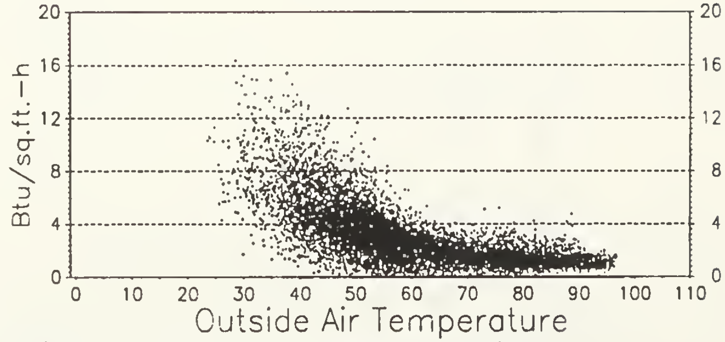
Pre-Retrofit (05/31/1989 - 11/28/1990)

Everyday



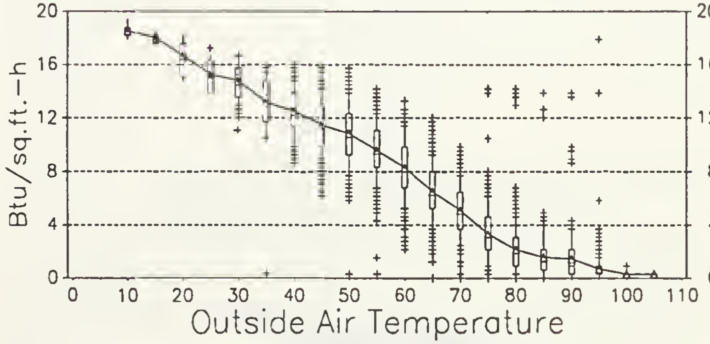
Post-Retrofit (03/06/1991 - 12/31/1994)

Everyday

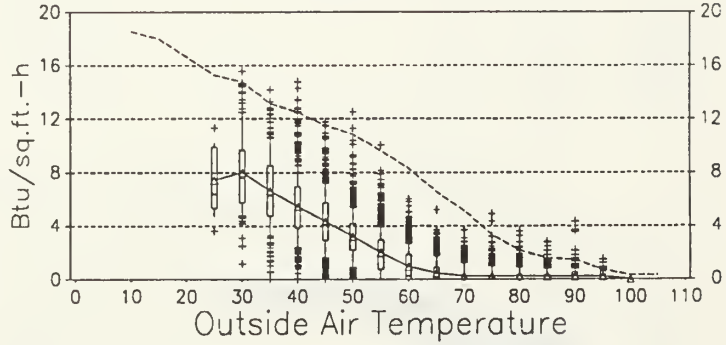


Note: Data in graphs above has been vertically offset randomly up to 1 Btu/sq.ft.-h to improve graphical presentation.

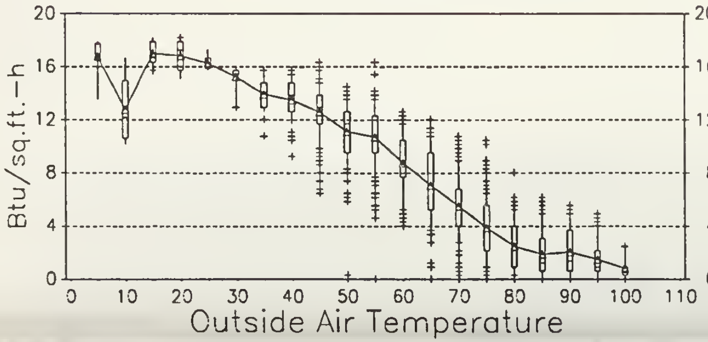
Weekdays



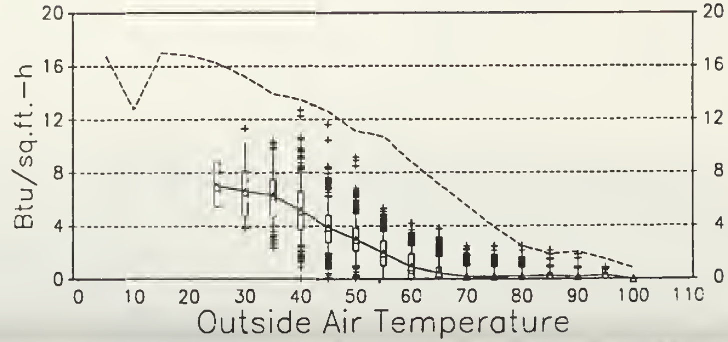
Weekdays



Weekends



Weekends

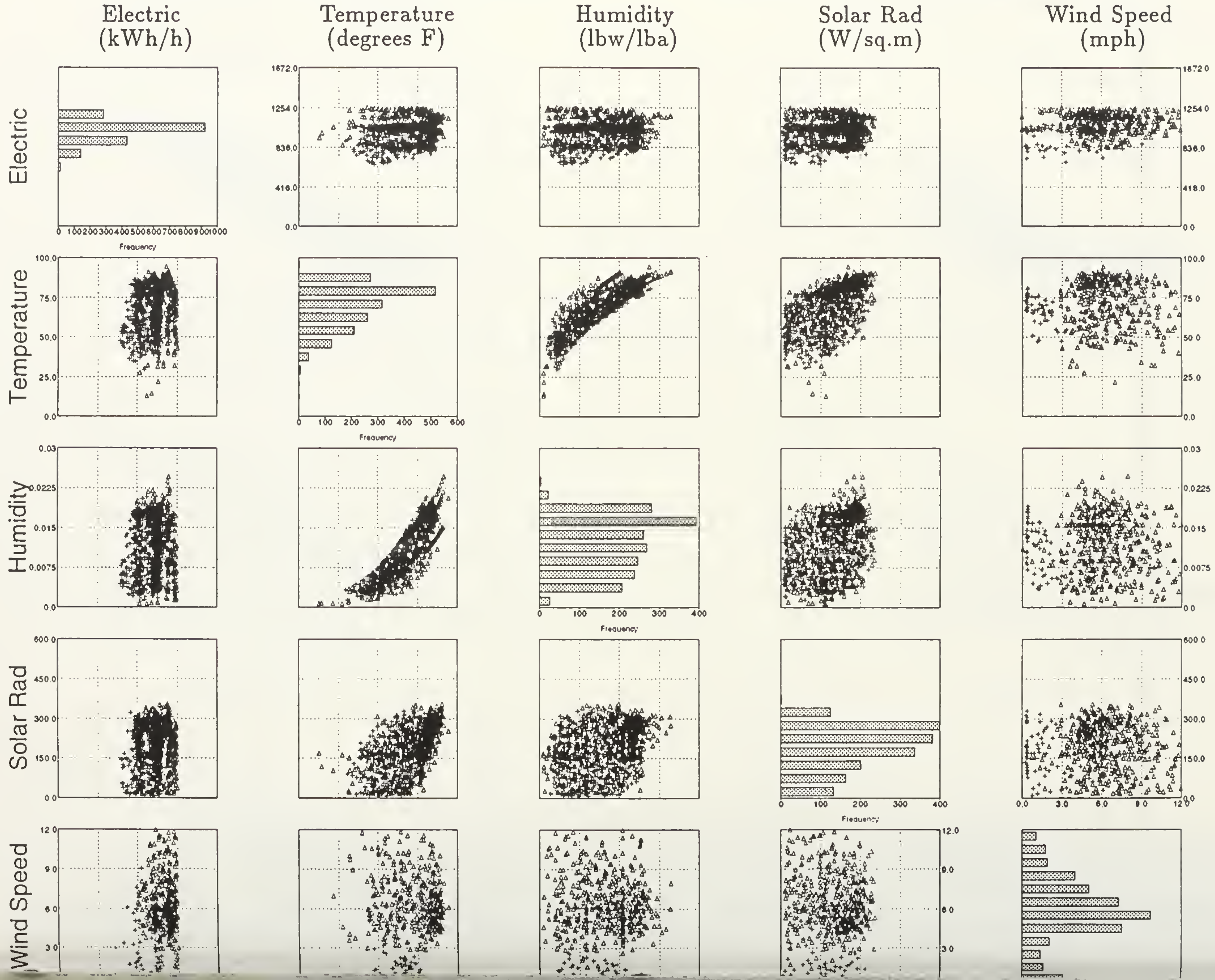


Tab D-7

Carpet Plots of Energy Use versus Ambient Conditions with Juxtaposed Histograms

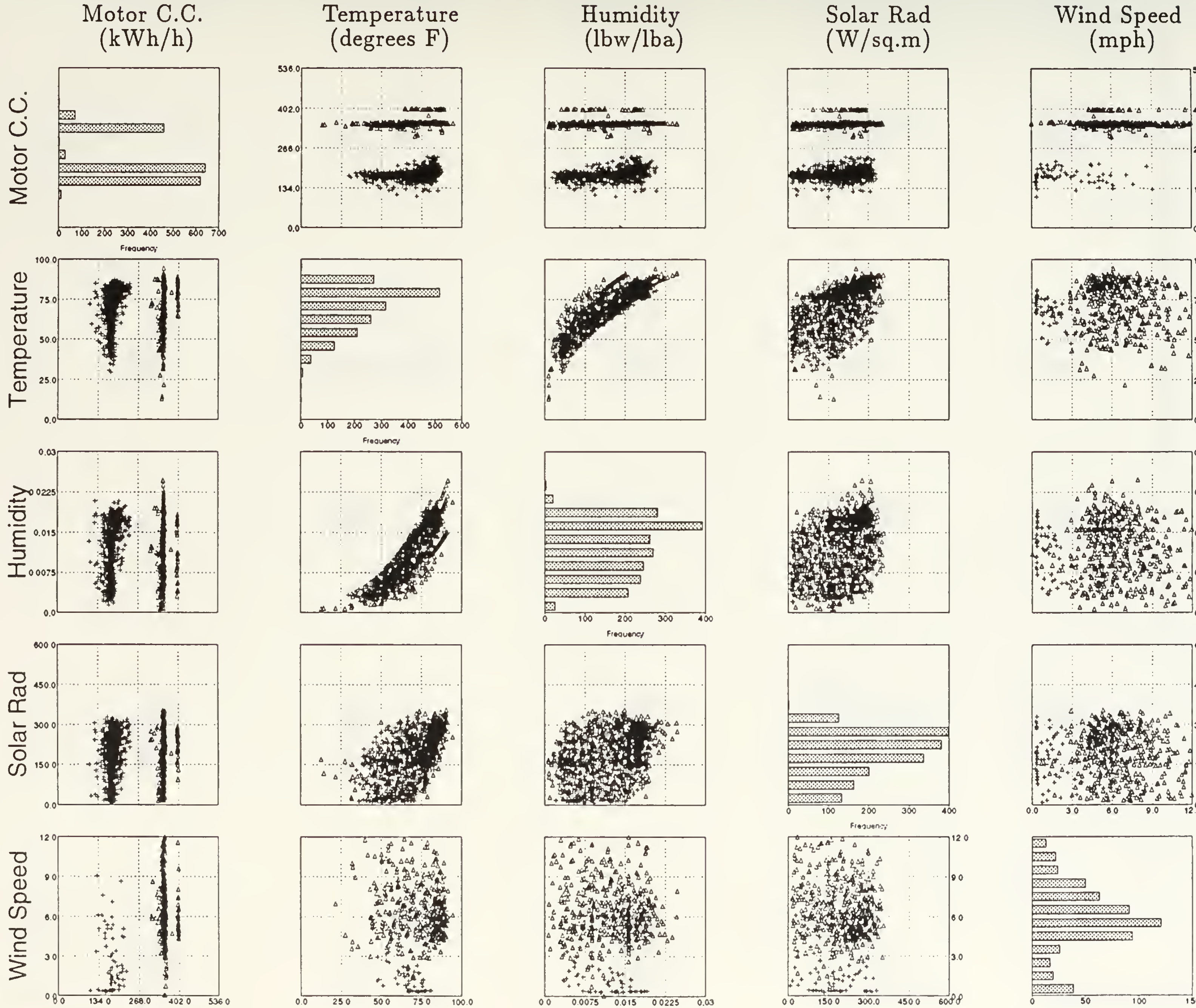
Zachry Engineering Center (ZEC)
Daily Average Values

Pre-Retrofit (△) 05/31/1989 - 11/28/1990 Post-Retrofit (+) 03/06/1991 - 12/31/1994



Zachry Engineering Center (ZEC)
Daily Average Values

Pre-Retrofit (△) 05/31/1989 - 11/28/1990 Post-Retrofit (+) 03/06/1991 - 12/31/1994

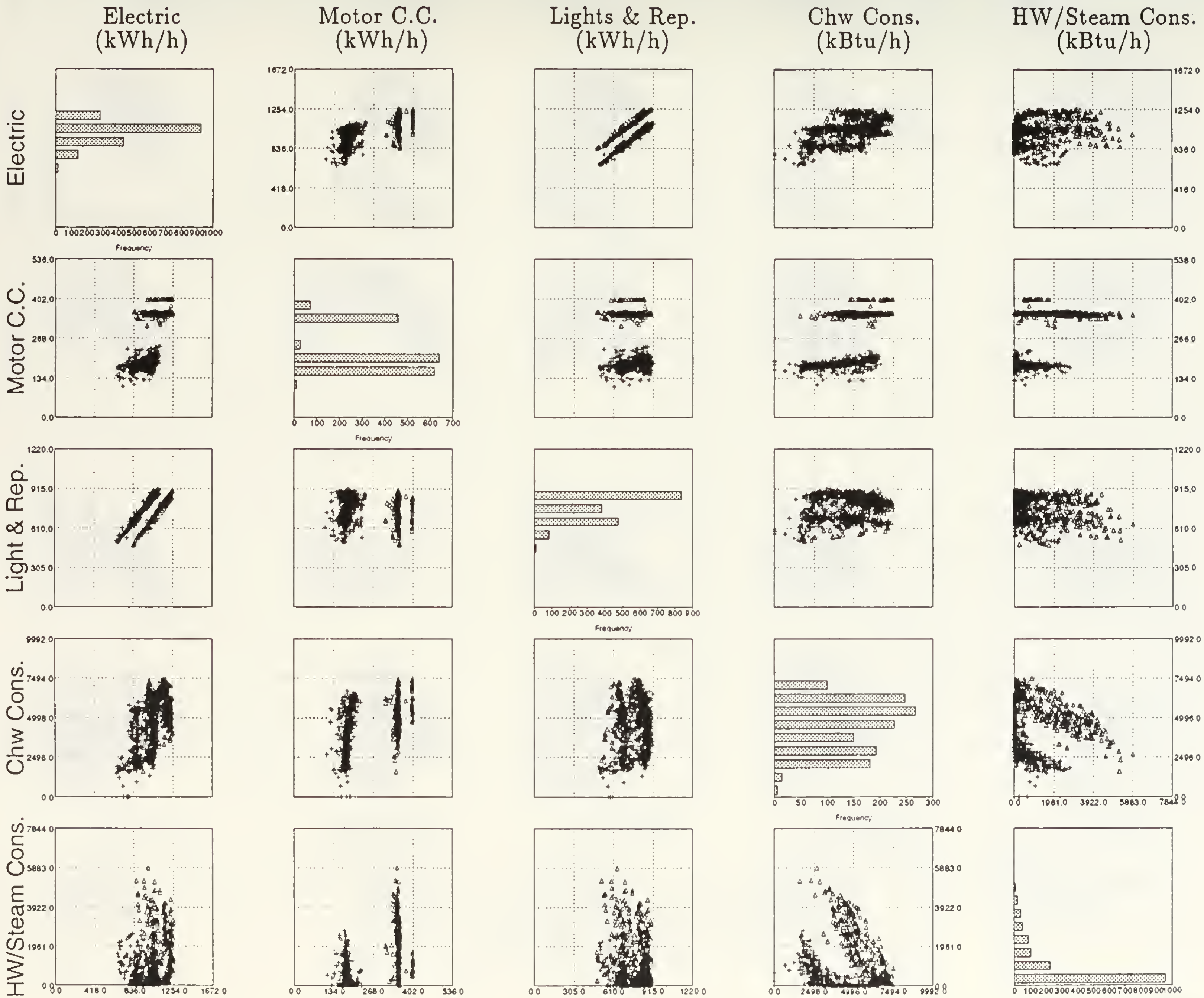


Tab D-8

Carpet Plots of One Energy Channel Use Against Other Energy Use Channels

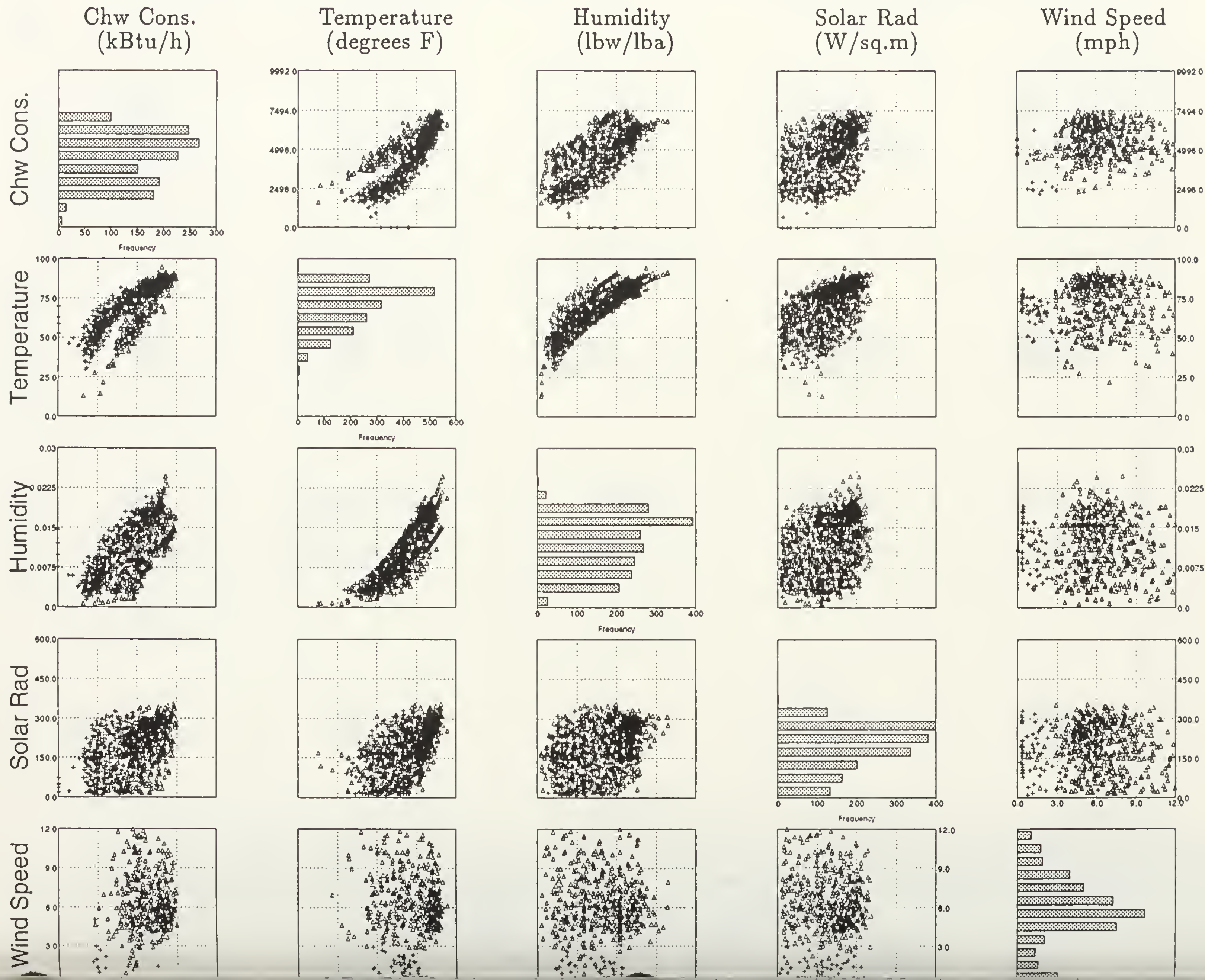
Zachry Engineering Center (ZEC)
Daily Average Values

Pre-Retrofit (△) 05/31/1989 - 11/28/1990 Post-Retrofit (+) 03/06/1991 - 12/31/1994



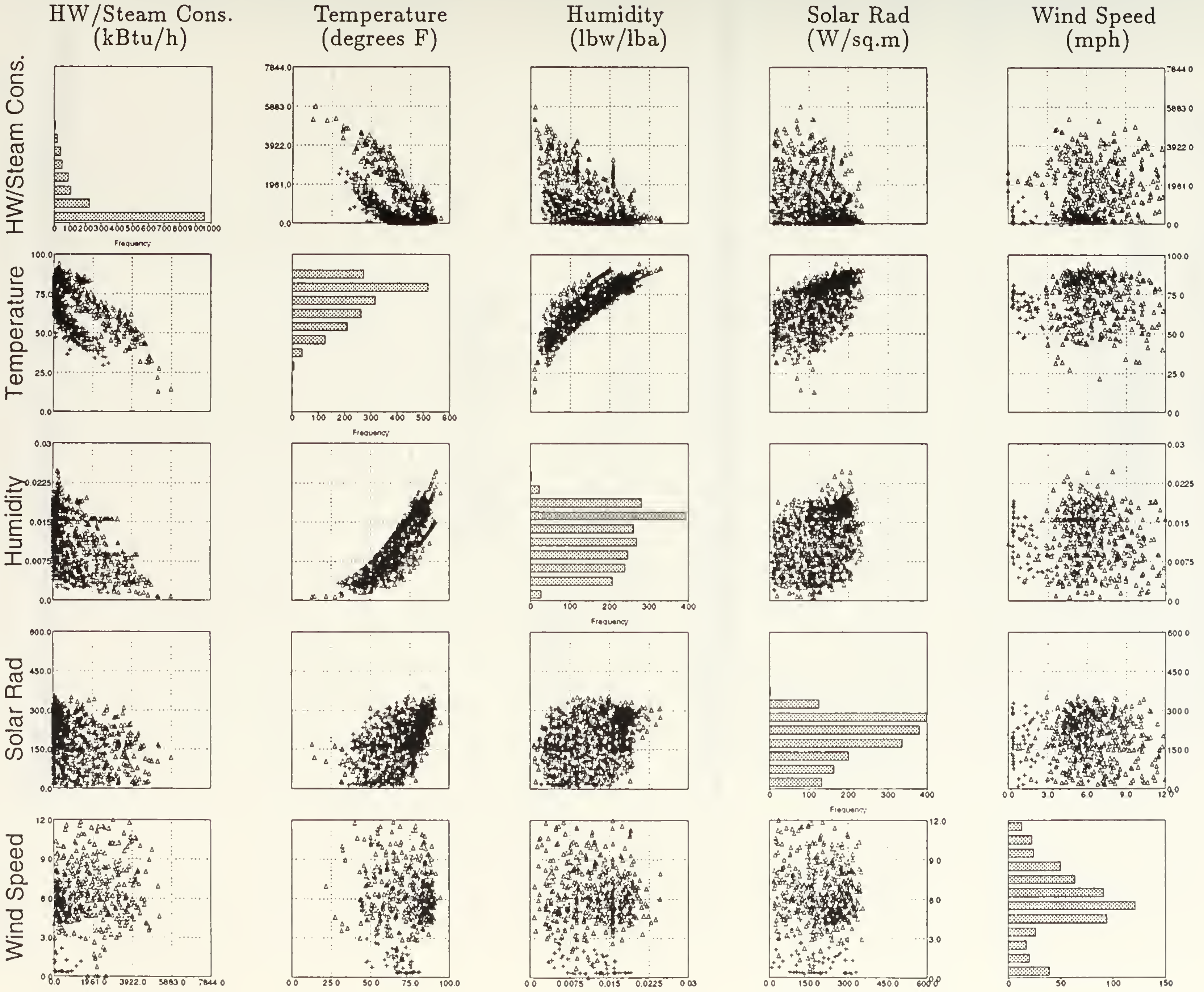
Zachry Engineering Center (ZEC)
Daily Average Values

Pre-Retrofit (Δ) 05/31/1989 - 11/28/1990 Post-Retrofit (+) 03/06/1991 - 12/31/1994



Zachry Engineering Center (ZEC)
Daily Average Values

Pre-Retrofit (△) 05/31/1989 - 11/28/1990 Post-Retrofit (+) 03/06/1991 - 12/31/1994



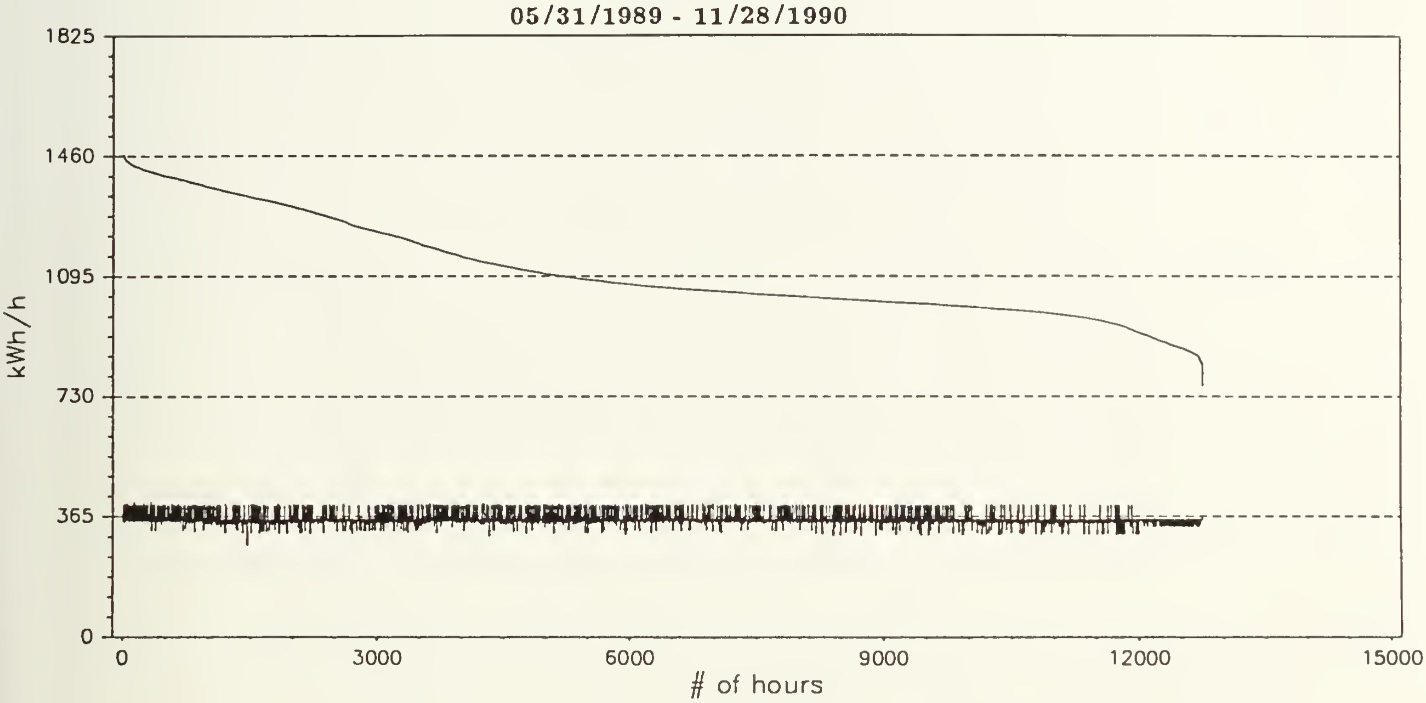
Tab D-9

Coincident Cumulative Frequency Plots

Zachry Engineering Center (ZEC)
W.B. Electric & M.C.C. as kWh/h

Pre-Retrofit Period

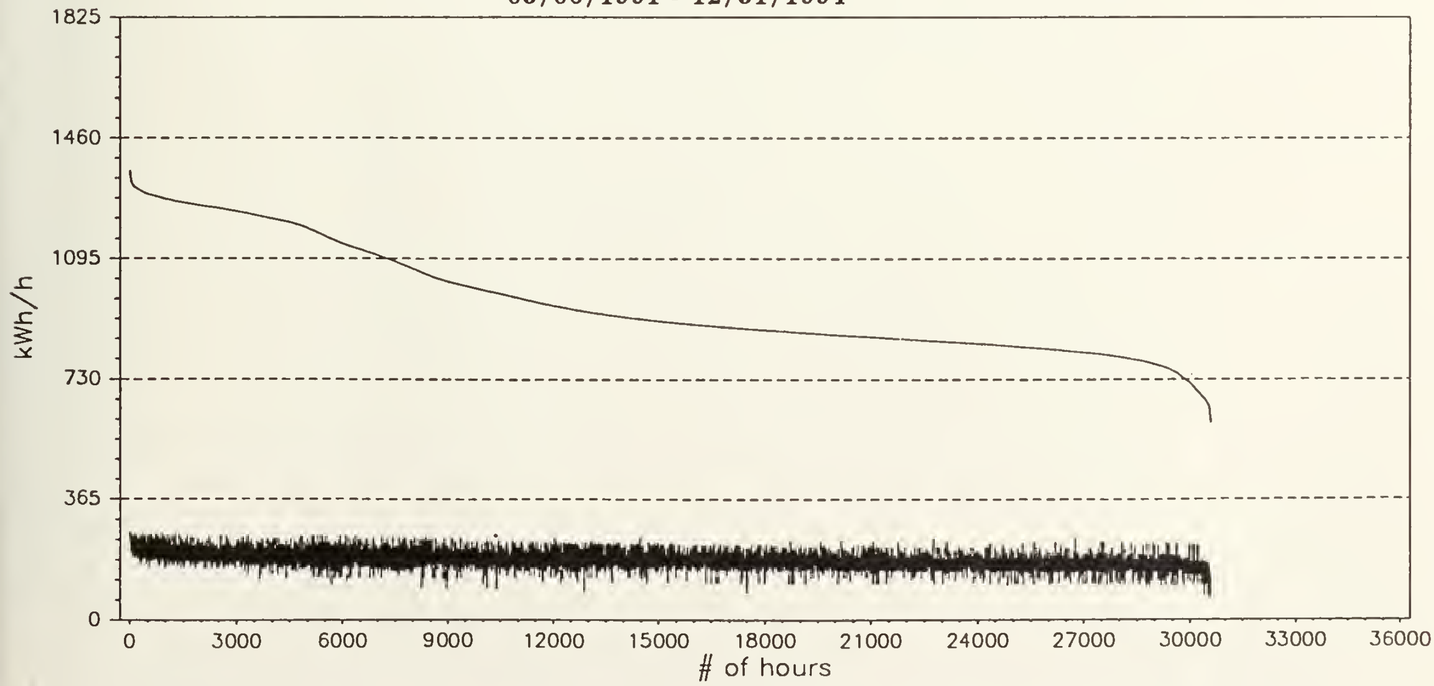
05/31/1989 - 11/28/1990



upper line = W.B. Electric
lower line = M.C.C.

Post-Retrofit Period

03/06/1991 - 12/31/1994



upper line = W.B. Electric
lower line = M.C.C.